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(71) Applicant: HOYA CORPORATION
Shinjuku-ku Tokyo 161 (JP)

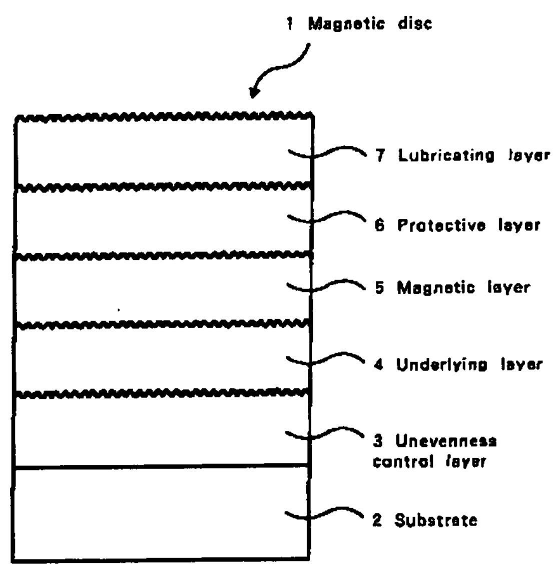
(72) Inventors:
- ZOU, Xuelu,
Hoya Corporation
Tokyo 161 (JP)
- TORATANI, Hisayoshi,
Hoya Corporation
Tokyo 161 (JP)

(74) Representative:
Godemeyer, Thomas, Dr.
Hauptstrasse 58
51491 Overath (DE)

(54) GLASS FOR INFORMATION RECORDING MEDIUM SUBSTRATE AND GLASS SUBSTRATE

(57) Disclosed is SiO_2-Al_2O_3-RO (RO = divalent metal) glass having high specific elastic modulus of 36 x 10^6 Nm/kg or more or high Young's modulus of 110 GPa or more, high transition temperature of 700°C or higher (high heat resistance). The glass exhibits excellent surface smoothness (surface roughness Ra < 9Å) and high strength, which can provide glass substrate with high strength. Since glass substrates being composed of the glass having excellent heat resistance and flatness, the substrates can be subjected to heat treatment for improvement of magnetic layer characteristics without any decomposition of the substrate and realize smaller flying height of magnetic head, i.e., higher recording density. The glasses exhibiting high specific elastic modulus and high strength enables to realize thinner magnetic discs and prevent breakdown of magnetic discs.

Fig. 1



Description

Field of the Invention

The present invention relates to glass and glass substrate suitably used for substrates of information recording media such as magnetic discs and optical discs, heat resistant substrates of low temperature polycrystalline silicon liquid crystal display devices, which are expected as next generation LCDs, substrates for various electric and electronic components and the like. In particular, it relates to glass suitable for substrates of information recording media and the like, which exhibits high specific elastic modulus and/or Young's modulus and high heat resistance and, when used as a substrate, realizes excellent surface smoothness.

Description of the Related Art

Major components of magnetic storage devices of electronic computers and the like are a magnetic recording medium and a magnetic head for reconstruction of magnetically recorded information. Flexible discs and hard disks have been known as magnetic recording media. As substrates for hard discs (magnetic discs), for example, aluminum substrates, glass substrates, ceramic substrates, carbon substrates and the like have been known. In practical use, however, an aluminum substrate or a glass substrate is mainly used according to the intended size and the use thereof.

Recently, flying height of magnetic heads is markedly reduced as hard disc drivers for notebook personal computers are made smaller and their magnetic recording density made higher. Accordingly, extremely high precision has been demanded for the surface smoothness of magnetic disc substrates.

However, it is difficult to produce smooth surface more than a certain level of precision with an aluminum alloy. That is, even though it is polished by using highly precise abrasives and processing apparatuses, the polished surface may suffer from plastic deformation because of the low hardness of the alloy. Even if the aluminum alloy is plated with nickel-phosphorous, the surface roughness Ra cannot be made 20Å (angstrom) or less. In addition, as hard disk drivers are made smaller and thinner, a further smaller thickness of substrates for magnetic discs is also strongly desired. However, it is difficult to produce such a thin disc with an aluminum alloy having a certain strength defined by specification of hard disk drivers because of low strength and stiffness of aluminum alloy.

Therefore, glass substrates for magnetic discs having high strength, high stiffness, high impact resistance and high surface smoothness have been developed. Because glass substrates have excellent surface smoothness and mechanical strength, they have been paid much attention as substrates for present and future use. For example, as such glass substrates, chemically tempered glass substrates whose surfaces are strengthened by the ion exchange technique, crystallized glass substrates subjected to crystallization treatment, alkali-free glass substrates which do not substantially contain alkaline substances and the like have been known well.

For example, as a chemically tempered glass substrate, Japanese Patent Unexamined Publication No. Hei 1-239036 (referred to as Reference 1 hereinafter) discloses a glass substrate for magnetic recording media strengthened by subjecting to ion exchange treatment a glass material for the substrate containing, indicated in terms of % by weight, 60-70% of SiO_2, 0.5-14 % of Al_2O_3, 10-32% of R_2O where R is an alkali metal, 1-15% of ZnO and 1.1-14% of B_2O_3.

As a crystallized glass, Japanese Patent Unexamined Publication No. Hei 7-187711 (referred to as Reference 2 hereinafter) discloses a glass substrate for magnetic recording media containing, indicated in terms of % by weight, 50-65% of SiO_2, 18-25% of CaO, 6-11% of Na_2O, 6-12% of K_2O, 0-2.5% of Al_2O_3 and 5-9% of F and containing kanasite as main crystals. U.S. Patent No. 5,391,522 (referred to as Reference 3 hereinafter) discloses a crystallized glass substrate for magnetic discs containing 65-83% of SiO_2, 8-13% of Li_2O, 0-7% of K_2O, 0.5-5.5% of MgO, 0-5% of ZnO, 0-5% of PbO, (provided that Mgo + ZnO + PbO is 0.5-5%), 1-4% of P_2O_5, 0-7% of Al_2O_3 and 0-2% of As_2O_3 + Sb_2O_3 and containing microcrystalline particles of $Li_2O \cdot 2SiO_2$ as main crystals.

As an alkali-free glass, Japanese Patent Unexamined Publication No. Hei 8-169724 (referred to as Reference 4 hereinafter) discloses a glass substrate for magnetic discs having a composition containing, indicated in terms of % by weight, 35-55% of SiO_2 + Al_2O_3, 0-10% of B_2O_3, 40-60% of CaO + BaO, provided that CaO $\geqq$ 5%, 0-10% of ZnO + SrO + MgO, 0-5% of TiO_2, 0-5% of ZrO_2, 0-1% of As_2O_3 and/or Sb_2O_3.

Recent HDDs (hard disk drivers) have been required to have higher recording capacity to meet higher performance of personal computers, and a smaller and thinner disc substrate, smaller flying height of magnetic heads and higher revolution speed of discs have been required to meet smaller size and higher performance of personal computers. It is expected that the thickness of 2.5-inch diameter disc substrates should become thinner from the present thickness 0.635 mm to a thickness of 0.43 mm, or even 0.38 mm. In addition, for recent higher recording density of 3.5-inch hard discs for servers and higher data processing speed, requirement for stiffness of substrate materials becomes increasingly severer, and conventional aluminum substrates seem to almost reach their limits of performance. It is expected that further higher capacity and smaller size of hard discs will be sought in future. Therefore, smaller thickness, higher strength, more excellent surface smoothness, higher impact resistance and the like of substrates for magnetic recording

media will be further strongly demanded.

However, as disc substrates become thinner, they become more likely to suffer deflexion and warp. On the other hand, as higher recording density is sought, lower flying height of magnetic heads and higher revolution speed of magnetic discs are further sought yet, and such deflexion and warp of substrates may cause breakdown of magnetic discs. However, if thickness of conventional glass substrates is made thinner than currently used, the problems due to the deflexion and warp mentioned above will become unacceptably marked and thus thinner discs cannot be realized.

Degree of deflexion and warp of substrates can be evaluated from specific elastic modulus (= Young's modulus/specific gravity) or Young's modulus of substrate material. Materials of higher specific elastic modulus are required for suppressing the problems of the deflexion and warp of substrates made with a smaller thickness. Further, materials of higher Young's modulus are required for suppressing the problems of the deflexion of substrates to be rotated at a high speed.

The above situation may be further explained as follows. That is, with recent improvements on smaller size, higher capacity and higher speed of HDDs, it is expected that the thickness of 3.5-inch discs currently used of 0.8 mm will be made smaller to 0.635 mm, and 0.635 mm of current 2.5-inch discs to 0.43 mm, or even to 0.38 mm. Revolution speed of substrates is also expected to be made faster from the current maximum speed of 7200 rpm to 10000 rpm, or even to 14000 rpm. As substrates for such magnetic recording media become thinner, they become more likely to suffer deflexion, undulation and warp, and it is expected that, as the revolution speed becomes higher, stress loaded on the substrates (force exerted by wind pressure caused by rotation of discs) will become larger. Based on the theory of dynamics, the deflexion W of a disc receiving load of P per unit area is represented by the following formula:

$$W \propto \frac{Pa^4}{h^3 E}$$

wherein <u>a</u> represents an outer diameter of disc, <u>h</u> represents a thickness of substrate and E represents Young's modulus of disc material.

In static state, force loaded on the disc is the gravitation alone, and the deflexion W is represented by the following formula:

$$W \propto \frac{hda^4}{h^3 E} = \frac{da^4}{h^2 E} = \frac{a^4}{h^2 G}$$

wherein <u>d</u> represents a specific gravity of disc material and G is a specific elastic modulus of disc material (= Young's modulus/specific gravity).

On the other hand, supposing that the gravitational force is balanced by centrifugal force and can be ignored in rotating state of disc, force loaded on the disc may be considered only wind pressure caused by the rotation of the disc. The wind pressure is represented as a function of disc revolution speed and said to be proportional to the second power of the speed. Accordingly, the deflexion W when the disc is rotating in a high speed is represented by the following formula:

$$W \propto \frac{(rpm)^2 a^4}{h^3 E}$$

Therefore, in order to suppress the deflexion W of substrate to be rotated at a high speed, a material of high Young's modulus E is required. According to the present inventors' calculation, when the thickness of 2.5-inch substrate is made smaller from 0.635 mm to 0.43 mm, and the thickness of 3.5-inch substrate from 0.8 mm to 0.635 mm, a substrate material having a specific elastic modulus higher than that of conventional materials should be required. Further, when the current revolution speed of 3.5-inch high-end substrates of 7200 rpm is made faster to prospective 10000 rpm, an aluminum substrate having Young's modulus of around 70 GPa cannot meet such a high speed, and a new substrate material having a further higher Young's modulus should be required. As the specific elastic modulus or Young's modulus of substrate material becomes higher, not only stiffness of substrates becomes higher, but also impact resistance and strength of substrates become higher. Therefore, a glass material having high specific elastic modulus and high Young's modulus is strongly desired in the field of HDD production.

There are further properties of substrates for magnetic recording media required for realizing higher recording density other than the specific elastic modulus and Young's modulus. One of those is high heat resistance, and another is high surface smoothness. In order to obtain higher recording density of magnetic recording media, it is necessary to

enhance magnetic characteristics such as magnetic coercive force of magnetic layer (magnetic recording layer). While coercive force of magnetic layer may vary depending on the kind of magnetic material used, coercive force of the magnetic material may be enhanced by heat-treatment even if the same material is used. Therefore, separating from development of new magnetic materials, it may be desirable to treat a magnetic layer formed on a substrate at a higher temperature in order to obtain higher coercive force using a conventional material. It is also possible to obtain higher recording density by making flying height of magnetic heads smaller. Therefore, the flying height of magnetic heads will be further made smaller in future. To realize smaller flying height of magnetic heads, good smoothness of disc surfaces and hence good smoothness of substrate surfaces are required.

The chemically tempered glass disclosed in Reference 1 has a glass transition point of around 500°C. However, to improve coercive force of magnetic layer, heat treatment at a temperature higher than 500°C is effective. Accordingly, heat resistance of the chemically tempered glass of Reference 1 itself is insufficient. Chemically tempered glasses are generally made by providing an ion exchanged layer with alkali metal ions on surfaces of the glasses. However, when a magnetic layer is formed on the surface of a chemically tempered glass and heat-treated, the ions in the ion exchanged layer may disadvantageously migrate to the magnetic layer and adversely affect it. The migration of the alkali metal ions to the magnetic layer is more activated as the temperature becomes higher. To suppress the migration of alkali metal ions, heat treatment at a lower temperature is desirable. Thus, when chemically tempered glass substrates are used, it is difficult to improve magnetic characteristics by heat treatment at a high temperature and it is difficult to obtain magnetic recording media having high coercive force. The above chemically tempered glass has a specific elastic modulus of about 30 x 10^6 Nm/kg and Young's modulus of about 80 GPa, and hence exhibits poor stiffness. Therefore, it cannot be used for 3.5-inch high-end disc substrates and thinner disc substrates. Moreover, chemically tempered glass substrates have stress layers on both surfaces, and these stress layers may cause deflexion when the stress layers do not have uniform and equivalent stress. Therefore, it is difficult to realize smaller flying height of magnetic heads and high-speed rotation with chemically tempered glass.

The conventional crystallized glasses such as those disclosed in References 2 and 3 exhibit excellent heat resistance because they do not show transition. However, glass substrates for magnetic recording media are required to have more excellent surface smoothness as higher recording density is attempted. This is because higher recording density of magnetic recording media requires a smaller flying height of magnetic heads. However, because crystallized glass contains many microparticles, they hardly afford substrates of a surface roughness (Ra) of 10Å or less. As a result, substrates have poor surface smoothness and surface configuration of discs is degraded. An unevenness control layer, for example, is formed on substrates to prevent a magnetic head from being absorbed to magnetic discs. However, it is difficult to control surface homology of such an unevenness control layer provided on a substrate of crystallized glass.

The alkali-free glass disclosed in Reference 4 has a high transition temperature as high as 730°C at most. However, it has a specific elastic modulus of only 27-34 x 10^6 Nm/kg and Young's modulus of around 70-90 GPa, and hence it can no way meet the demand of further thinner magnetic disc substrates.

As a substrate of excellent heat resistance, the carbon substrate disclosed in Japanese Patent Unexamined Publication No. Hei 3-273525 (referred to as Reference 5 hereinafter) can be mentioned. However, the carbon substrate has a specific elastic modulus of around 15-19 x 10^6 Nm/kg and hence it is inferior to glass in mechanical strength. Therefore, it can hardly meet the demand for a thinner substrate required for the production of smaller magnetic discs. In addition, carbon substrates have many surface defects and hence it is difficult to realize higher recording density with them.

Thus, no oxide glass which has high specific elastic modulus or Young's modulus, exhibits high heat resistance and excellent surface smoothness (surface roughness ≦ 5Å) and can be produced in a large scale at low cost is currently found in the market. Even the SiO_2-Al_2O_3-MgO glasses, which is well known as commercially available oxide glass of high Young's modulus, have a Young's modulus of around 80-90 GPa at most.

Therefore, an object of the present invention is to provide a novel glass material satisfying high strength, high impact resistance, high specific elastic modulus, high heat resistance and high surface smoothness required for the production of smaller and thinner substrates for information recording media of higher recording density in future.

More specifically, the object of the present invention is to provide a glass substrate having a specific elastic modulus of 36 x 10^6 Nm/kg or more and glass transition temperature of 700°C or higher, not containing microcrystalline particles, and exhibiting high surface smoothness (surface roughness Ra of 9 Å or less).

A further object of the present invention is to provide a glass substrate having a Young's modulus of 110 GPa or more, preferably a glass transition temperature of 700 °C or higher, not containing microcrystalline particles, and exhibiting high surface smoothness (surface roughness Ra of 9Å or less).

Degree of deflexion and warp of disc substrates can be estimated from specific elastic modulus (= Young's modulus/specific gravity) of the material composing the substrate. In order to suppress deflexion and warp of thinner substrates to the extent that such problems do not occur, materials with higher specific elastic modulus are required. However, in a certain glass composition, effects added to specific elastic modulus by glass components have not been well known.

An object of the present invention is to provide a novel glass exhibiting higher specific elastic modulus than those presently known by establishing theoretical relation between specific elastic modulus and glass composition, focussing on SiO_2-Al_2O_3-RO glasses (wherein R is a bivalent metal) which are preferred as substrates for information recording media such as magnetic discs, and investigating effects of glass components to specific elastic modulus.

A further object of the present invention is to provide substrates for information recording media using the above glass and information recording media using the above substrate.

SUMMARY OF THE INVENTION

Therefore, in order to provide glass materials having a specific elastic modulus G of 36×10^6Nm/kg or more or a Young's modulus of 110 GPa or more, the present inventors have designed novel glass compositions based on the theoretical calculation suggested by themselves and conducted various experiments and researches. As a result, it was found that novel glass which has a high specific elastic modulus and/or high Young's modulus not obtained so far, excellent surface smoothness and high heat resistance and producible in a large scale at a low cost can be obtained by using components greatly contributing to the improvement of Young's modulus such as Al_2O_3, Y_2O_3, MgO, TiO_2 and rare earth metal oxides in a large amount. In addition, with respect to SiO_2-Al_2O_3-RO glasses, new glass materials exhibiting higher specific elastic modulus than those presently known have been found. Based on this finding, the present invention has been completed.

The present invention is described hereinafter.

Glass for substrates having a specific elastic modulus G of 36×10^6 Nm/kg or more (hereinafter referred to Glass (1)).

Glass containing, as oxides constituting the glass, SiO_2: 25-52%, Al_2O_3: 5-35%, MgO: 15-45%, Y_2O_3: 0-17%, TiO_2: 0-25%, ZrO_2: 0-8%, CaO: 1-30%, provided that Y_2O_3 + TiO_2 + ZrO_2 + CaO: 5-30% and B_2O_3 + P_2O_5: 0-5%, in molar %, and having a specific elastic modulus of 36×10^6Nm/kg or more (hereinafter referred to Glass (2)).

Glass having a composition containing, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 10-37%, MgO: 5-40%, TiO_2: 1-25%, in molar %, and having a specific elastic modulus of 36×10^6 Nm/kg or more (hereinafter referred to Glass (3)).

Glass having a composition containing, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 20-40%, CaO: 8-30%, Y_2O_3: 2-15%, in molar %, and having a specific elastic modulus of 36×10^6 Nm/kg or more (hereinafter referred to Glass (4)).

Glass for substrates having a Young's modulus of 110 GPa or more (hereinafter referred to Glass (5)).

Glass having a composition containing, as oxides constituting the glass, SiO_2: 30-60%, Al_2O_3: 2-35%, MgO: 0-40%, Li_2O: 0-20%, Y_2O_3: 0-27%, La_2O_3: 0-27%, CeO_2: 0-27%, Pr_2O_3: 0-27%, Nd_2O_3: 0-27%, Sm_2O_3: 0-27%, Eu_2O_3: 0-27%, Gd_2O_3: 0-27%, Tb_2O_3: 0-27%, Dy_2O_3: 0-27%, Ho_2O_3: 0-27%, Er_2O_3: 0-27%, Tm_2O_3: 0-27%, Yb_2O_3: 0-27%, provided that Y_2O_3 + La_2O_3 + CeO_2 + Pr_2O_3 + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_2O_3 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3: 1-27% and Li_2O + MgO + Y_2O_3 + La_2O_3 + CeO_2 + Pr_2O_3 + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_2O_3 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3 > 25%, in molar %,and having a Young's modulus of 110 GPa or more (hereinafter referred to Glass (6)).

Material composed of SiO_2-Al_2O_3-RO glass used for information recording media wherein R is a bivalent metal characterized in that said glass contains 20 molar % or more of Al_2O_3 (hereinafter referred to Glass (7)).

Material composed of SiO_2-Al_2O_3-RO glass used for information recording media wherein R is a bivalent metal characterized in that said glass contains 20 molar % or more of MgO as RO (hereinafter referred to Glass (8)).

Material composed of SiO_2-Al_2O_3-RO glass used for information recording media wherein R is a bivalent metal characterized in that said glass further contains Y_2O_3 (hereinafter referred to Glass (9)).

Glass for information recording media (glass (10) hereinafter) characterized in that it contains one or more than two metal oxides which are selected from the group consisting of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, Y, Zr, Nb, Mo, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Hf, Ta, and W in the range of 3-30 molar %.

A substrate for information recording media composed of the above glass material and a magnetic disc comprising said substrate and magnetic layer thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic cross-sectional view of a magnetic disc 1 comprising a glass substrate 2, on which an unevenness control layer 3, underlying layer 4, magnetic layer 5, protective layer 6 and lubricating layer 7 are provided in this order.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be further explained hereinafter.

The term "glass" used in the present invention means glass which does not substantially contain crystal grains, and does not mean those called as crystallized glass or glass ceramics containing at least 20% of crystal grains.

Glass (1)

Glass (1) is a glass for substrate characterized in that it has a specific elastic modulus G of 36×10^6 Nm/kg or more.

When the specific elastic modulus G is less than 36×10^6 Nm/kg, a substrate made of the glass exhibits severe deflexion, and, for example, a substrate of such glass having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation may exhibit a maximum deflexion of 1.4 μm or more. As a result, flying stability of magnetic heads cannot be obtained and hence reconstruction of recorded information cannot be performed stably. To obtain a substrate exhibiting a maximum deflexion of 1.25 μm or less, glass having a specific elastic modulus G of 37×10^6Nm/kg or more is preferred. Glass having a specific elastic modulus of 42×10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflexion of 1.4 μm or less even if it is made as a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45×10^6 Nm/kg or less.

Glass (1) is glass whose surface roughness (Ra) can be made 9Å or less, in addition to having a specific elastic modulus G of 36×10^6 Nm/kg or more. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 9Å or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, glass whose surface roughness (Ra) can be made 5Å or less is preferred.

Glass (1) is glass having a transition temperature of 700°C or more, in addition to having a specific elastic modulus G of 36×10^6 Nm/kg or more and/or being possible to have surface roughness (Ra) of 9Å or less. Because of a transition temperature of 700°C or higher, heat resistance of substrate higher than that of the conventional one can be obtained, in addition to the reduced deflexion. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

As specific examples of glass (1) having the above characteristics, glasses (2), (3) and (4) can be mentioned. These glasses are oxide glasses comprising cations having a small ionic radius, strong chemical bonding force and high packing density in the glass structure in order to satisfy the characteristics of glass (1).

Glass (2)

Glass (2) is a composition constituted mainly for obtaining a high specific elastic modulus, and has a specific elastic modulus G of 36×10^6 Nm/kg or more. A glass having specific elastic modulus G of 36×10^6 Nm/kg or more can afford a substrate exhibiting reduced deflexion. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it may exhibit a maximum deflexion of 1.4 μm or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be performed stably. To obtain a substrate exhibiting a maximum deflexion of 1.25 μm or less, glass having a specific elastic modulus G of 37×10^6Nm/kg or more is preferred. Glass having a specific elastic modulus of 42×10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflexion of 1.4 μm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45×10^6 Nm/kg or less.

Glass (2) can have a surface roughness (Ra) of 9Å or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 9Å or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 5Å or less is preferred.

Glass (2) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflexion, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

SiO_2 acts to form the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, oxide glass containing more than 52% of SiO_2 as a main component of the glass no longer exhibits a specific elastic modulus exceeding 36×10^6 Nm/kg, and

therefore the content of SiO_2 is suitably 52% or less. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass, and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-52%, preferably in the range of 30-50%.

Al_2O_3 is very important as a component for imparting high heat resistance and high durability to glass and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, a content of Al_2O_3 less than 5% cannot sufficiently improve Young's modulus of glass. When the content of Al_2O_3 exceeds 35%, MgO, which is a component contributing to improvement of specific elastic modulus of glass, cannot be introduced in a sufficient amount and hence melt characteristics of glass at a high temperature is also degraded. Therefore, the content of Al_2O_3 is suitably in the range of 5-35%, preferably in the range of 7-32%.

MgO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass. In particular, when the content of Al_2O_3 is less than 20%, it is preferred to introduce a large amount of MgO in order to maintain high specific elastic modulus of glass. However, sufficiently stable glass suitable for large scale production cannot be obtained with a MgO content exceeding 45%. On the other hand, if the content of MgO is less than 15%, Young's modulus of glass tends to be lowered. Therefore, the content of MgO is suitably in the range of 15-45%, preferably in the range of 22-40%.

Y_2O_3 is a component introduced for enhancing crystallization stability of glass and improving durability and melt characteristics of glass at a high temperature. In particular, introduction of a small amount of Y_2O_3 markedly contributes to enhancement of specific elastic modulus of glass and improvement of glass homogeneity. However, while Y_2O_3 improves Young's modulus of glass, too much amount of Y_2O_3 steeply increases the specific gravity of glass and hence disadvantageously tends to degrade the specific elastic modulus of the glass. Therefore, the content of Y_2O_3 is suitably 17% or less, preferably 15% or less. To obtain distinct effects of the addition of Y_2O_3, the content of Y_2O_3 is preferably 0.5% or more.

TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves melt characteristics of glass, enhances structure stability and improves durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. In particular, in glass containing large amounts of MgO, Al_2O_3 and the like, TiO_2 improves melt characteristics at a high temperature and crystallization stability of glass and is surely expected to enhance specific elastic modulus of glass in combination with other oxides such as MgO and Al_2O_3. However, when too much of TiO_2 is introduced, glass tends to show phase separation and hence disadvantageously degrade crystallization stability and homogeneity of glass. Therefore, the content of TiO_2 is suitably 25% or less, preferably 20% or less, To obtain distinct effects of the addition of TiO_2, the content of TiO_2 is preferably 1% or more.

CaO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics at a high temperature like MgO. CaO, like MgO, also contributes to improvement of crystallization stability of glass and homogeneity of glass. As described above, when the content of Al_2O_3 is less than 20%, it is preferred to introduce a large amount of MgO to maintain high specific elastic modulus of glass. In such a case, CaO is a component introduced mainly for improving melt characteristics at a high temperature and crystallization stability of glass. However, glass having crystallization stability suitable for large scale production cannot be obtained with a content of CaO exceeding 30%. Therefore, the content of CaO is suitably 30% or less, preferably 27% or less. In order to obtain distinct effects of the addition of CaO, the content of CaO is preferably 2% or more.

ZrO_2 is a component introduced mainly for enhancing durability and stiffness of glass. Addition of ZrO_2 in a small amount improves heat resistance of glass and also enhances crystallization stability against devitrification. However, the content of ZrO_2 exceeds 8%, melt characteristics of glass at a high temperature is remarkably degraded, and surface smoothness of glass deteriorates and specific gravity increases. Therefore, the content of ZrO_2 is suitably 8% or less, preferably 6% or less. In order to obtain distinct effects of the addition of ZrO_2, the content of ZrO_2 is preferably 0.5% or more.

$Y_2O_3 + TiO_2 + ZrO_2 + CaO$ is suitably in the range of 1-30%. These components are for contributing to enhancement of Young's modulus of glass and enhancement of crystallization stability. When the total amount of these components is less than 1%, Young's modulus of glass tends to be lowered and crystallization stability of glass tends to be degraded. On the other hand, these components increase specific gravity of glass, and hence introduction in a large amount may lower the specific elastic modulus of glass. Therefore, the total content of $Y_2O_3 + TiO_2 + ZrO_2 + CaO$ is suitably in the range of 1-30%, preferably in the range of 5.5-27%.

P_2O_5 and B_2O_3 are components added for controlling melt characteristics of glass at a high temperature. For example, introduction of P_2O_5 and B_2O_3 in a small amount does not substantially affect on specific elastic modulus of glass

but significantly lower high temperature viscosity of glass. Therefore, it is very effective for facilitating melting of glass. For improvement of melt characteristics of glass and control of crystallization stability and physical characteristics of glass, the total amount of B_2O_3 + P_2O_5 is suitably 5% or less, preferably 3.5% or less. In order to obtain distinct effects of the addition of B_2O_3 and P_2O_5, the total content is preferably 0.5% or more.

As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if too much of the degassing agents is added, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

The other components such as V_2O_5, Cr_2O_3, ZnO, SrO, NiO, CoO, Fe_2O_3, CuO etc. may be added for controlling melt characteristics at a high temperature, physical properties and the like of glass. For example, by adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiating with a heat lamp can be effectively performed. For improving melt characteristics of glass and controlling crystallization stability and physical properties of glass, the total amount of ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 +B_2O_3 + P_2O_5+ V_2O_5 is suitably 5% or less, preferably 4% or less.

Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

The above-mentioned glass is alkali-free glass which does not substantially contain alkali substances. Therefore, when a film is formed on a substrate made of this glass, any alkali substances do not migrate into the film and hence the film is not adversely affected.

Glass (3)

Glass (3) is a composition constituted mainly for obtaining a high specific elastic modulus, and the glasses have a specific elastic modulus G of 36 x 10^6 Nm/kg or more. Glass having specific elastic modulus G of 36 x 10^6 Nm/kg or more can afford a substrate exhibiting reduced deflection. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it may exhibit a maximum deflection of 1.4 μ m or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be stably performed. To obtain a substrate exhibiting a maximum deflection of 1.25 μm or less, glass having a specific elastic modulus G of 37 x 10^6Nm/kg or more is preferred. Glass having a specific elastic modulus of 42 x 10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflection of 1.4 μm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45 x 10^6 Nm/kg or less.

Glass (3) can have a surface roughness (Ra) of 9Å or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 9Å or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 5Å or less is preferred.

Glass (3) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflection, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

SiO_2 acts as an oxide for forming the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, glass containing more than 50% of SiO_2 cannot contain a large amount of Al_2O_3 which is a component contributing to improvement of impact resistance and mechanical strength of glass. Therefore, in order to obtain glass having a high specific elastic modulus, the upper limit of the SiO_2 content is suitably 50%. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is suitably 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-50%, preferably in the range of 30-49%.

Al_2O_3 is very important as a component for imparting high heat resistance and high durability to glass and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's

modulus and heat resista[illegible] glass as a skeletal structure-forming componen[illegible] is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, when MgO is used with a content of 25% or less in order to further enhance flexural strength and impact resistance, a content of Al_2O_3 less than 10% cannot sufficiently improve Young's modulus of glass and hence a desired specific elastic modulus cannot be obtained. When the content of Al_2O_3 exceeds 37%, melt characteristics of glass at a high temperature is degraded, and hence homogenous glass cannot obtained and crystallization stability of glass is degraded. Therefore, the upper limit of the content of Al_2O_3 is suitably 37%. The content of Al_2O_3 is suitably in the range of 10-37%, preferably in the range of 11-35%.

MgO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass. In particular, when Al_2O_3, which is a component for greatly improving Young's modulus of glass, is introduced in a large amount, MgO is preferably used for improving stability of glass structure as well as lowering melt characteristics at a high temperature to facilitate melting of glass. However, sufficiently stable glass suitable for large scale production containing a large amount of Al_2O_3 for enhancing impact resistance and strength of glass cannot be obtained with a MgO content exceeding 40%. On the other hand, with a content of MgO of less than 5%, glass exhibiting sufficient stability and high specific elastic modulus cannot be obtained. Therefore, the content of MgO is suitably in the range of 5-40%, preferably in the range of 7-35%.

TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves melt characteristics of glass and enhances structure stability and durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. In particular, in glass containing a large amount of Al_2O_3, TiO_2 improves melt characteristics at a high temperature and crystallization stability of the glass and is surely expected to enhance specific elastic modulus of the glass in combination with Al_2O_3. However, when the content of TiO_2 exceeds 25%, glass tends to show phase separation and hence crystallization stability and homogeneity of glass tend to be disadvantageously degraded. On the other hand, addition of TiO_2 of 1% or more markedly improves melt characteristics of glass at a high temperature. Therefore, the content of TiO_2 is suitably in the range of 1-25%, preferably in the range of 2-20%.

Y_2O_3 is a component introduced for improving Young's modulus, enhancing crystallization stability of glass and improving durability and melt characteristics at a high temperature of glass. In particular, when a large amount of Al_2O_3 is introduced for enhancing flexural strength, impact resistance and the like, Y_2O_3 exerts excellent effect as a melting aid for Al_2O_3. For example, when Al_2O_3 of 25% or more is introduced into glass, homogenous glass can be obtained by adding Y_2O_3. However, since Y_2O_3 is relatively expensive, a smaller content is preferred from economical point of view. In addition, while a proper amount of Y_2O_3 greatly contributes to enhancement of specific elastic modulus of glass, when the content of Y_2O_3 exceeds 17%, increase of specific gravity overwhelms increase of Young's modulus of glass, and hence the addition can no longer contribute to improvement of specific elastic modulus of the glass. Therefore, the content of Y_2O_3 is suitably in the range of 0-17%, preferably in the range of 1-15% depending on the introduced amount of Al_2O_3.

CaO is a component capable of enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature like MgO. CaO also contributes to improvement of crystallization stability of glass and homogeneity of glass. When a large amount of Al_2O_3 is introduced as a component greatly contributing to improvement of Young's modulus of glass, it is preferred to introduce CaO to improve stability of glass structure and to lower high temperature viscosity to facilitate melting. When the content of CaO exceeds 25%, glass containing a large amount of Al_2O_3 for enhancing impact resistance and strength of glass and having crystallization stability suitable for large scale production cannot be obtained. Therefore, the upper limit of the content of CaO is suitably 25%. In order to obtain distinct effects of the addition of CaO, the content of CaO is preferably 2% or more.

ZrO_2 is a component introduced mainly for enhancing durability and stiffness of glass. Addition of a small amount of ZrO_2 improves heat resistance of glass and also enhances crystallization stability against devitrification. However, when the content of ZrO_2 exceeds 8%, melt characteristics of glass at a high temperature is markedly degraded, and surface smoothness of glass deteriorates and specific gravity increases. Therefore, the content of ZrO_2 is suitably 8% or less, preferably 6% or less. In order to obtain distinct effects of the addition of ZrO_2, the content of ZrO_2 is preferably 0.5% or more.

As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if the amount of the degassing agents is too much, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible used for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

The other components such as P_2O_5, V_2O_5, B_2O_3, Cr_2O_3, ZnO, SrO, NiO, CoO, Fe_2O_3, CuO etc. may be added for controlling melt characteristics at a high temperature and physical properties and the like of glass. For example, addition of a small amount of P_2O_5 does not substantially affect specific elastic modulus of glass but significantly lower

high temperature viscosity of glass and hence it is effective for facilitating melting of glass. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed. For improving melt characteristics of glass at a high temperature and controlling physical and thermal properties of glass, the total amount of ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5+ V_2O_5 is suitably 5% or less.

Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

When Li_2O is contained in the glass, chemical tempering treatment by ion exchange can be performed to enhance strength of the glass. On the other hand, when the glass is alkali-free glass not containing Li_2O, any alkali substances do not migrate into a film formed on a substrate and hence the film is not adversely affected.

Glass (4)

Glass (4) is a composition constituted mainly for obtaining a high specific elastic modulus, and the glasses have a specific elastic modulus G of 36 x 10^6 Nm/kg or more. Glass having specific elastic modulus G of 36 x 10^6 Nm/kg or more can afford a substrate exhibiting reduced deflection. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it exhibits a maximum deflection of 1.4 μm or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be stably performed. To obtain a substrate exhibiting a maximum deflection of 1.25 μm or less, glass having a specific elastic modulus G of 37 x 10^6Nm/kg or more is preferred. Glass having a specific elastic modulus of 42 x 10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflection of 1.4 μm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45 x 10^6 Nm/kg or less.

Glass (4) can have a surface roughness (Ra) of 9Å or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 9Å or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 5Å or less is preferred.

Glass (4) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflection, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

SiO_2 acts as an oxide for forming the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, oxide glass of CaO-Al_2O_3-SiO_2 system containing more than 50% of SiO_2 no longer exhibits a specific elastic modulus exceeding 36 x 10^6 Nm/kg, and therefore the content of SiO_2 is suitably 50% or less. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-50%, preferably in the range of 30-50%.

Al_2O_3 is very important as a component for imparting high heat resistance and high durability and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, a content of Al_2O_3 less than 20% cannot sufficiently improve Young's modulus of glass. On the other hand, when the content of Al_2O_3 exceeds 40%, melt characteristics of glass at a high temperature is degraded and hence homogenous glass cannot obtained, and crystallization stability of glass is also degraded. Therefore, the content of Al_2O_3 is suitably in the range of 20-40%, preferably in the range of 21-37%.

CaO is a component for enhancing stiffness and strength of glass and improving melt characteristics at a high temperature. It also contributes to improvement of crystallization stability of glass and homogeneity of glass. In particular, when a large amount of Al_2O_3 is introduced as a component greatly contributing to improvement of Young's modulus of glass, it is necessary to introduce CaO to improve stability of glass structure and to lower high temperature viscosity to facilitate melting of glass. However, when the content of CaO is less than 8%, crystallization stability of glass is markedly degraded. On the other hand, when the content of CaO exceeds 30%, Young's modulus of glass tends to be lowered. Therefore, the content of CaO is suitably in the range of 8-30%, preferably in the range of 10-27%.

Y_2O_3 is a component introduced for improving Young's modulus, enhancing crystallization stability of glass and improving durability and melt characteristics of glass at a high temperature. In particular, when a large amount of Al_2O_3 is introduced for enhancing Young's modulus of glass, Y_2O_3 exerts excellent effect as a melting aid for Al_2O_3. For example, when Al_2O_3 of 25% or more is introduced into glass, homogenous glass can be obtained by adding Y_2O_3 as a melting aid. However, since Y_2O_3 is relatively expensive, its content is preferably a relatively small amount, i.e., 15% or less depending on the properties required for glass. On the other hand, the content of Y_2O_3 is too small, melt characteristics of glass at a high temperature is degraded and specific elastic modulus of glass is lowered. Therefore, the lower limit of the content of Y_2O_3 is suitably 2%. Accordingly, the content of Y_2O_3 is suitably in the range of 2-15%, preferably in the range of 3-12%.

MgO is a component for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass, and improves specific elastic modulus. This component may optionally be added as desired. However, when the content of MgO exceeds 20%, the essential component, CaO, cannot be introduced in a large amount and thus crystallization stability tends to be lowered. Therefore, the upper limit of the content of MgO is suitably 20%. In order to obtain distinct effects of addition of MgO, its content is preferably 5% or more.

TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves solubility of glass and enhances structure stability and durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. However, if too much amount of TiO_2 is introduced into CaO-Al_2O_3-SiO_2 system oxide glass, the glass tends to show phase separation and crystallization stability and homogeneity are disadvantageously degraded. Therefore, the content of TiO_2 is suitably 25% or less, preferably 20% or less. In order to obtain distinct effects of addition of TiO_2, its content is preferably 1% or more.

Li_2O is a component mainly for lowering high temperature viscosity of glass to facilitate melting. In particular, when the Al_2O_3 content is high, addition of small amount of Li_2O is very effective for obtaining homogenous glass. However, if its content is too high, durability of glass is degraded and Young's modulus tends to be lowered. Therefore, the content of Li_2O is suitably 15% or less, preferably 12% or less. In order to obtain distinct effects of the addition of Li_2O, the content of Li_2O is preferably 1.5% or more.

As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if the amount of the degassing agents is too much, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

The other components such as P_2O_5, V_2O_5, B_2O_3, Cr_2O_3, ZnO, SrO, NiO, CoO, Fe_2O_3, CuO etc. may be added for controlling melt characteristics at a high temperature and physical properties and the like of glass. For example, addition of a small amount of P_2O_5 does not substantially affect specific elastic modulus of glass but significantly lower high temperature viscosity of glass and therefore melting of glass is facilitated. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed. For controlling physical and thermal properties of glass, the total amount of $ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5$ is suitably 5% or less.

Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

Glass (5)

Glass (5) of the present invention is characterized in that it has a Young's modulus of 110 GPa or more.

If Young's modulus is less than 110 GPa, deflection of substrate caused by wind pressure becomes severe when the substrate is rotated at a speed of 7200 rpm or more and stable head flying cannot be obtained, and hence reconstruction of recorded information cannot be stably performed. To obtain stable flying of heads, Young's modulus is preferably 120 GPa or more, particularly preferably 130 GPa or more. While Young's modulus as high as possible is desired, it is practically about 150 GPa or less.

Glass (5) is glass whose surface roughness (Ra) can be made 9Å or less, in addition to having a Young's modulus of 110 GPa or more. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 9Å or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, glass whose surface roughness (Ra) can be made 5Å or less is preferred.

Glass (5) is glass having a transition temperature of 700°C or higher, in addition to having a Young's modulus of 110 GPa or more and/or being possible to have surface roughness (Ra) of 9Å or less. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one can be obtained, in addition to having the reduced deflection. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

As specific examples of glass (5) having the above characteristics, glass (6) can be mentioned. Glass (6) is an oxide glass comprising cations having a small ionic radius, strong chemical bonding force and high packing density in the glass structure in order to satisfy the above characteristics.

Glass (6)

SiO_2 acts as an oxide for forming the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, glass containing more than 60% of SiO_2 cannot contain a large amount of Al_2O_3, which is a component contributing to improvement of impact resistance and mechanical strength. Therefore, in order to obtain glass having a high Young's modulus, the SiO_2 content should be limited to 60% or less. On the other hand, if the SiO_2 content is too small, for example, less than 30%, crystallization stability of glass is significantly degraded and sufficiently stable glass suitable for large scale production cannot be obtained. Therefore, the content of SiO_2 is in the range of 30-60%, particularly preferably in the range of 32-55%.

Al_2O_3 is very important as a component for imparting high heat resistance and high durability to glass and also as a component for enhancing stability of the glass structure and stiffness of glass together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component absolutely essential for enhancing Young's modulus and improving heat resistance. When the content of Al_2O_3 exceeds 35%, melt characteristics of glass at a high temperature is degraded, and hence homogenous glass cannot be obtained and crystallization stability of glass is degraded. Therefore, the content of Al_2O_3 is 35% or less. In particular, it is preferably in the range of 1-30%.

MgO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass. In particular, when Al_2O_3, which is a component for greatly improving Young's modulus of glass, is introduced in a large amount, MgO is very important for improving stability of glass structure as well as lowering melt characteristics at a high temperature to facilitate melting of glass. However, when the MgO content exceeds 40%, crystallization stability sufficient for large scale production cannot be obtained for glass containing a large amount of Y_2O_3 or Al_2O_3 for enhancing impact resistance and strength of glass. Therefore, the content of MgO is suitably in the range of 0-40%. In particular, the content of MgO is preferably in the range of 5-35%.

Rare earth metal oxides such as Y_2O_3, La_2O_3, CeO_2, Pr_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, Gd_2O_3, Tb_2O_3, Dy_2O_3, Ho_2O_3, Er_2O_3, Tm_2O_3 and Yb_2O_3 are components introduced for improving Young's modulus, enhancing crystallization stability, and improving durability and melt characteristics of glass at a high temperature. In particular, when a large amount of Al_2O_3 is introduced into glass for enhancing flexural strength and impact resistance of glass, the role of the rare earth metal oxides as a melting aid of Al_2O_3 cannot be ignored. For example, when 20% or more of Al_2O_3 is introduced into glass, Y_2O_3 is an indispensable component for the production of homogeneous glass. However, because rare earth metal oxides are relatively expensive, they are preferably added in an amount as small as possible depending on the desired Young'smodulus. If too much amount of rare earth metal oxide is added, while Young's modulus of glass increases, specific gravity also markedly increases. On the other hand, addition of rare earth metal oxide in a proper amount greatly contributes to improvement of Young's modulus of glass. Therefore, the total amount of rare earth metal oxides is suitably in the range of 1-27% depending the Young's modulus desired for glass used as magnetic disc substrates. In particular, the total content of the rare earth metal oxides is preferably in the range of 2-20 %.

Li_2O is a component very useful for improving melt characteristics of glass at a high temperature. In addition, addition of small amount of Li_2O advantageously and markedly reduces specific gravity of glass without significantly changing Young's modulus of glass. Glass containing Li_2O even in a small amount is advantageous for the production of high strength glass, because it can be chemically tempered by ion exchange. However, the content of Li_2O is too high, crystallization stability of glass tends to be lowered. Therefore, the content of Li_2O is suitably 20% or less, preferably 15% or less. In order to obtain distinct effects of the addition of Li_2O, the content of Li_2O is preferably 2% or more.

In addition, it is suitable that total amount of $Li_2O + MgO + Y_2O_3 + La_2O_3 + CeO_2 + Pr_2O_3 + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_2O_3 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3$ is more than 25% to increase glass crystallizing stability, and improve glass homogeneity, glass durability, and melting at high temperature.

TiO_2 acts as both of a [illegible] skeletal structure-forming component and a mo[illegible]g component. It lowers high temperature viscosity, improve[illegible]t characteristics of glass and enhances structure[illegible]lity and durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of the glass. In particular, in glass containing a large amount of MgO or Al_2O_3, TiO_2 improves melt characteristics at a high temperature and crystallization stability of the glass and is surely expected to enhance specific elastic modulus of the glass in combination with Al_2O_3. However, too much amount of TiO_2 is introduced, glass tends to show phase separation and hence crystallization stability and homogeneity of glass are disadvantageously degraded. Therefore, the content of TiO_2 is suitably 20% or less. In particular, its content is preferably 15% or less. In order to obtain distinct effects of addition of TiO_2, its content is preferably 2% or more.

ZrO_2 is a component introduced mainly for enhancing durability and stiffness of glass. Addition of small amount of ZrO_2 improves heat resistance of glass and also enhances crystallization stability against devitrification. However, when the content of ZrO_2 exceeds 8%, melt characteristics of glass at a high temperature is markedly degraded, and surface smoothness of glass deteriorates and specific gravity increases. Therefore, the content of ZrO_2 is suitably 8% or less, preferably 6% or less. In order to obtain distinct effects of the addition of ZrO_2, the content of ZrO_2 is preferably 0.5% or more.

CaO, ZnO, NiO and Fe_2O_3 are components introduced mainly for improving melt characteristics at a high temperature and crystallization stability of glass. These components has a large cationic radius and effective for improving crystallization stability when introduced into glass together with MgO. However, if too much amount of them are introduced, specific gravity of glass increases and Young's modulus decreases. Therefore, the total content of CaO, ZnO, NiO and Fe_2O_3 is suitably 15% or less, preferably 12% or less. In order to obtain distinct effects of the addition of these components, the total content is preferably 1% or more.

As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if the amount of the degassing agents is too much, specific gravity of glass is increased and Young's modulus tends to be lowered. In addition, they may react with and damage a platinum crucible used for melting. Therefore, the content of $As_2O_3 + Sb_2O_3$ is preferably 2% or less, more preferably 1.5% or less.

The other components such as SrO, CoO, FeO, CuO, Cr_2O_3, B_2O_3, P_2O_5, V_2O_5, etc. may be added for controlling melt characteristics at a high temperature, physical properties and the like of glass. For example, addition of a small amount of P_2O_5 does not substantially affect specific elastic modulus of glass but significantly lower high temperature viscosity of glass and therefore melting of glass is facilitated. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed. For improving melt characteristics of glass at a high temperature and physical and thermal properties of glass, the total amount of ZnO + SrO + NiO + CoO + FeO + CuO + Cr_2O_3 + B_2O_3 + P_2O_5+ V_2O_5 is suitably 8% or less.

Other than the basic components mentioned above, impurities including a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended characteristics of the glass according to the present invention.

Common items in Glasses (7)-(9)

In SiO_2-Al_2O_3-RO glasses of the present invention, SiO_2, one of major components of the glass, acts as an oxide for forming the network structure of glass and is a component for improving crystallization stability of glass structure. The SiO_2 content preferably ranges 25-55 molar %. If the SiO_2 content is less than 25 molar %, crystallization stability of glass is significantly degraded and sufficiently stable glass suitable for large scale production cannot be obtained. If the SiO_2 content exceeds 55 molar %, specific elastic modulus and Young's modulus of glass is significantly degraded. The SiO_2 content is more preferably in the range of 30-50 molar %.

Bivalent metal oxide represented by RO may be selected from MgO, CaO, ZnO, NiO and the like and does not limited to these oxides.

In order to improve specific elastic modulus and Young's modulus of glass, it is preferred to add at least one of TiO_2 and ZrO_2. The content of TiO and/or ZrO_2 is suitably more than 5 molar % in order to improve specific elastic modulus and Young's modulus of glass. TiO_2 enables to improve Young's modulus without increasing of specific gravity of glass. However, if too much of TiO_2 is introduced, glass tends to show phase separation and hence crystallization stability and homogeneity of glass are disadvantageously degraded. Therefore, the content of TiO_2 is suitably 25 molar % or less, preferably 20 molar % or less. The content of ZrO_2 is preferably 8molar % or less. If the ZrO_2 content exceeds 8 molar %, melt characteristics of glass at a high temperature is markedly degraded, and surface smoothness of glass deteriorates and specific gravity increases. More preferably, the content of ZrO_2 is 6 molar % or less.

In order to improve melting properties, LiO_2 may be introduced. Since too much of LiO_2 tends to lower Young's modulus of glass, a small amount, for example 2 molar % or less, of LiO_2 is preferably introduced. It is possible to sub-

ject glasses containing LiO_2 to [illegible]ically strengthen treatment by ion exchange. Wh[illegible] thin film is formed on a substrate made of alkali-free glass [illegible]h do not contain LiO_2, any alkali substances do n[illegible]grate into the film and hence the film is not adversely affected.

In order to improve crystallization stability and the like, B_2O_3, P_2O_5, V_2O_5, GeO_2, Ga_2O_3, HfO_2, etc. may be added. As_2O_3 and/or Sb_2O_3 (e.g. 3 molar % or less) may be added as degassing agents in order to obtain homogenous glass. ZnO, SrO, NiO, CoO, Fe_2O_3, CuO, Cr_2O_3, B_2O_3, P_2O_5, V_2O_5 etc. may be added for controlling melt characteristics at a high temperature, physical properties and the like of glass. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed.

Glass (7)

Glass (7) contains 20 molar % or more of Al_2O_3. In SiO_2-Al_2O_3-RO glasses, glass with higher Al_2O_3 content exhibits higher specific elastic modulus. Glasses with 20 molar % or more of Al_2O_3 exhibit 38 x 10^6 Nm/kg or more of specific elastic modulus which are higher than that of conventional glass for information recording media. The upper limit of Al_2O_3 content is preferably 40 molar %. When the content of Al_2O_3 exceeds 40 molar %, melt characteristics of glass at a high temperature and crystallization stability would be degraded. When glass contains 20 molar % or more of Al_2O_3, it is suitable to introduce at least one selected from MgO and CaO as RO. When glass contains a lot of Al_2O_3, these components act to improve stability of glass structure and facilitate melting of glass by reducing glass viscosity at a high temperature. However, if too much amount of these components are added, crystallization stability may be degraded. Therefore, the content of MgO + CaO is suitably in the range of 15-40 molar %.

Glass (8)

Glass (8) contains 20 molar % or more of MgO as RO. In SiO_2-Al_2O_3-RO glasses, glass with higher MgO content exhibits higher specific elastic modulus. Glasses with 20 molar % or more of MgO exhibit 38 x 10^6 Nm/kg or more of specific elastic modulus which are higher than that of conventional glass for information recording media. The upper limit of Mg content is preferably 45 molar %. When the content of MgO exceeds 45molar %, crystallization stability may be degraded. The content of MgO preferably ranges 20-40 molar %.

When glass contains 20 molar % or more of MgO , it is suitable to introduce 5-40 molar % of Al_2O_3. If the content of Al_2O_3 is 5 molar % or less, crystallization stability may be degraded. If the content of Al_2O_3 exceeds 40 molar %, melt characteristics of glass at a high temperature and crystallization stability may be degraded.

CaO as RO may be added other than MgO. CaO act to improve melt characteristics of glass at a high temperature and crystallization stability. However, if too much of CaO is introduced, specific elastic modulus may be lowered. Therefore, the content of CaO is preferably 27molar % or less.

Glass (9)

Glass (9) further contains Y_2O_3. In SiO_2-Al_2O_3-RO glasses, specific elastic modulus can be improved by addition of Y_2O_3. The content of Y_2O_3 preferably ranges 0.5-17 molar %. Y_2O_3 is a component for enhancing Young's modulus and improving specific elastic modulus. However, a content of Y_2O_3 less than 0.5 molar % cannot sufficiently obtain the effects. On the other hand, when the content of Y_2O_3 exceeds 17 molar %, Y_2O_3 does not contribute to improvement of specific elastic modulus. In addition, a lower content of Y_2O_3 is preferred because it is expensive.

Effects of Y_2O_3 addition can be obtainable in SiO_2-Al_2O_3-RO glasses regardless of the contents of Al_2O_3 and MgO as RO, and Y_2O_3 can be added to the glasses of the present invention containing 20 molar % or more of Al_2O_3 or 20 molar % or more of MgO. In particular, addition of Y_2O_3 to glasses containing 20 molar % or more of Al_2O_3 is effective to improvement of specific elastic modulus and melt characteristics of glass at a high temperature.

Glass (10)

Glass (10) is glass for information recording media characterized in that it contains one or more than two metal oxides selected from the group consisting of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, Y, Zr, Nb, Mo, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Hf, Ta, and W in the range of 3-30 molar %.

It has been shown that an oxide of Y or Ti contributes to improve Young's modulus. Use of these substances are based on a theoretical idea of the present inventors that use of substances having high induction rate, which may increase glass filling density by introducing into glass, may increase Young's modulus of glass. In the same manner, by introducing metal oxides listed above which can increase glass filling density when they are introduced into glass in the range of 3-30 molar %, relatively high Young's modulus (e.g. 90 GPa or more) can be obtained. Such glass are highly

suitable for substrate for information recording media such as magnetic discs. When the amount of said metal oxides introduced is less than 3 molar %, the increase of Young's modulus of glass is insufficient, and is not preferable. Also, when the amount of said metal oxides introduced is over 30 molar %, glass crystallization stability and homogeneity may be degraded, or specific gravity is largely increased while specific elastic modulus is decreased, wherein these changes differs depending on kinds of the metal. Therefore it is not preferred. The lower limit of amount of said oxides introduced is, with the consideration of increase of Young's modulus, preferably 5 molar %, more preferably 10 molar %. And, the upper limit of an amount of said metal oxides introduced, with a consideration of glass crystallization stability, homogeneity, and specific elastic modulus, is preferably 25 molar %, more preferably 20 molar %.

Substrate for information recording media

Substrates for information recording media of the present invention characterized by being composed of one of the glasses (1)-(10) mentioned above. Examples of information recording media includes magnetic recording media, and examples of magnetic recording media includes magnetic discs such as hard discs. Size and shape of the substrate can be selected in view of its use. The substrate of the present invention is characterized by exhibiting high surface smoothness. High surface smoothness means 9 Å or less, preferably 5Å or less of surface roughness (Ra). Since distance between magnetic head and magnetic disc can be reduced by a magnetic disc using a substrate with high surface smoothness, higher recording density is obtainable.

Production method

The glass and the glass substrate of the present invention is not particularly limited, and can be produced by a conventional production method. For example, glass materials of a given composition can be melted by the high temperature melting method, i.e., melted in air or inert gas atmosphere, homogenized by bubbling, addition of degassing agent, stirring or the like and molded into plate glass by well-known press method, down draw method or the like. Then, substrates for magnetic recording media of a desired size and shape can be obtained from the plate glass by processing such as cutting and polishing. In the polishing, surface roughness (Ra) of 9Å, preferably 3-5Å can be obtained by wrapping or polishing with polishing powder of cerium oxide or the like.

Because the glass of the present invention is excellent in the heat-resistance, surface smoothness, chemical resistance, optical properties and mechanical strength, it can be suitably used for substrates of information recording media such as magnetic discs, glass substrates for magnet optical discs, glass substrates for optoelectronics such as those for optical discs, heat resistant substrates for low temperature polycrystalline silicon liquid crystal display devices, which are expected as next generation LCD, substrates for various electric and electronic components or the like.

<u>Magnetic disc</u>

A magnetic disc (hard disk) comprising a substrate composed of the glass of the present invention described above and at least a magnetic layer formed on a main surface of the substrate will be explained hereinafter.

As layers other than the magnetic layer, underlying layer, protective layer, lubricating layer, unevenness control layer and the like are optionally formed depending on functions of the disc. These layers can be formed by various thin film-forming techniques.

Material for the magnetic layer is not particularly limited. For example, in addition to Co magnetic layers, ferrite magnetic layers, iron-rare earth metal magnetic layers and the like can be mentioned. The magnetic layer may be either for horizontal magnetic recording or vertical magnetic recording.

Specific examples of the magnetic layer include, for example, those containing Co as a main component such as CoPt, CoCr, CoNi, CoNiCr, CoCrTa, CoPtCr and CoNiCrPt, CoNiCrTa, CoCrPtTa, CoCrPtSiO and the like. The magnetic layer may be consisted of multiple layers comprising a non-magnetic layer for noise reduction separating magnetic layers.

The underlying layer of the magnetic layer may be selected depending on the nature of the magnetic layer. For example, the underlying layer may be those comprising one or more of non-magnetic metals such as Cr, Mo, Ta, Ti, W, V, B and Al, oxides, nitride, carbides and the like of those metals. For a magnetic layer comprising Co as the main component, an underlying layer of pure Cr or Cr alloy is preferred for improving magnetic characteristics. The underlying layer is not limited to a monolayer, and may be composed of identical or nonidentical multiple layers. For example, the underlying layer may be a multi-layer underlying layer such as Al/Cr/CrMo and Al/Cr/Cr.

The unevenness control layer for preventing absorption of magnetic disc to magnetic head may be provided between the substrate and the magnetic layer or on the magnetic layer. Because surface roughness of the disc is properly controlled by the unevenness control layer, the magnetic disc is prevented from being absorbed to the magnetic disc and hence a highly reliable magnetic disc can be provided. Various materials and production methods for the une-

venness control layer have been known and they are not particularly limited. For example, the material of the unevenness control layer may be one or more metals selected from Al, Ag, Ti, Nb, Ta, Bi, S[illegible]Cr, Cu, Au, Sn, Pd, Sb, Ge, Mg and the like, alloys thereof, oxides, nitrides, carbides thereof and the like. For the ease of production, those produced from metals containing Al as a main component such as pure Al, Al alloys, Al oxides and Al nitrides are preferred.

For good head stiction, surface roughness of the unevenness forming layer is preferably Rmax of 50-300Å, more preferably Rmax of 100-200Å. When the Rmax is less than 50 Å, the disc surface is nearly flat, and hence the magnetic head and the disc are absorbed to each other. This may disadvantageously cause damage of the magnetic head and the magnetic disc, and head crash. On the other hand, when the Rmax exceeds 300Å, glide height becomes larger and recording density is disadvantageously lowered.

Unevenness may be provided on the surface of the glass substrate by a texturing treatment such as etching treatment and irradiation of laser lights instead of providing the unevenness control layer.

The protective layer may be, for example, a Cr layer, Cr alloy layer, carbon layer, zirconia layer, silica layer or the like. These protective layers can be successively formed by an inline sputtering apparatus together with the underlying layer, the magnetic layer and the like. These protective layers may have either monolayer structure or multilayer structure comprising identical or different layers.

Another protective layer may be provided on or instead of the protective layer explained above. For example, a silicon oxide (SiO_2) layer may be formed on the protective layer mentioned above by applying tetraalkoxysilane diluted in an alcoholic solvent, in which colloidal silica is further dispersed, and sintering the applied layer. This layer functions as both a protective layer and as an unevenness control layer.

While various kinds of layers have been proposed as the lubricating layer, it is generally formed by applying a liquid lubricating agent, perfluoropolyether, diluted in a solvent such as freons by dipping, spin coating, spraying or the like and subjecting the coated layer to a heat treatment as required.

EXAMPLES

The present invention will be further explained with reference to the following examples.

The glass compositions given in Examples 1-61 which are examples of glasses (1)-(4) are shown in Tables 1-5 and the glass compositions given in Examples 100-190 which are examples of glasses (5)-(6) are shown in Tables 6-13 in molar %. In addition, the glass compositions given in Examples 200-209 which are examples of glasses (7)-(9) are shown in Tables 14 in molar %. Most of these examples are examples of glass (10).

As the starting materials of these glasses, SiO_2, Al_2O_3, $Al(OH)_3$, MgO, $CaCO_3$, Y_2O_3, TiO_2, ZrO_2, Li_2CO_3 and the like were weighed into 250-300 g portions according to the given compositions shown in Tables 1-14 and mixed sufficiently to provide formulated batches. Each of them was charged in a platinum crucible and melted in air for 3 to 5 hours at 1550°C. After the melting, the glass melt was cast into a carbon mold having a size of 180 x 15 x 25 mm or Ø 67 x 5 mm, left to cool to the glass transition temperature, immediately transferred into an annealing furnace, annealed in the glass transition temperature range for about 1 hour and left to cool to room temperature in the furnace. The resulting glasses did not contain crystals deposited which can be observed by a microscope.

Glass pieces having a size of 180 x 15 x 25 mm were polished into pieces having a size of 100 x 10 x 10 mm or 10 x 10 x 20 mm and used as samples for measurements of Young's modulus, specific gravity and DSC. Glass discs of Ø 67 x thickness of 5 mm were polished into discs of Ø 65 x thickness of 0.5 mm and used as samples for measurement of surface roughness. The plate glass pieces of 10 x 1 x 20 mm were ground into 150 mesh powder, and 50 mg of the resulting powder were charged into a platinum pan and subjected to the DSC measurement using MAC-3300 DSC apparatus. The measurement of Young's modulus was achieved by the ultrasonic method using samples of 100 x 10 x 10 mm.

Values of surface roughness, specific gravity, Young's modulus, specific elastic modulus and transition temperature obtained in the measurements for the glasses of Examples 1-61 are shown in Tables 1-5 together with the glass compositions.

The obtained glasses were cut into discs and their main surfaces were polished with cerium oxide to afford magnetic disc substrates having a radius of outer circular periphery of 32.5 mm, radius of inner circular periphery of 10.0 mm and thickness of 0.43 mm. The results of deflection measurement of the obtained discs are also shown in Tables 1-5.

Values of surface roughness, Young's modulus and transition temperature obtained in the measurements for the glasses of Examples 100-190 are shown in Tables 6-13 together with the glass compositions.

Values of surface roughness, specific gravity, Young's modulus and specific elastic modulus obtained in the measurements for the glasses of Examples 200-209 are shown in Table 14 together with the glass compositions.

For comparison, compositions and characteristics of the ion exchanged glass substrate described in Japanese Patent Unexamined Publication No. Hei 1-239036 and the glass substrate described in Japanese Patent Unexamined Publication No. Hei 7-187711 are shown in Tables 5 and 13 as Comparative Examples 1 and 2.

Table 1

(molar %)

Example	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	49.00	45.00	44.00	45.00	40.00	45.00	45.00	34.00	30.00	35.00	35.00	35.00	40.00
Al_2O_3	21.00	20.00	17.00	12.50	12.50	10.00	7.50	17.00	15.00	15.00	17.00	15.00	20.00
MgO	25.00	25.00	21.00	30.00	30.00	30.00	30.00	15.00	15.00	15.00	20.00	20.00	30.00
CaO	5.00	10.00	14.00	5.00	5.00	5.00	5.00	20.00	20.00	15.00	13.00	10.00	—
Y_2O_3	—	—	—	7.50	7.50	5.00	7.50	—	—	—	—	5.00	5.00
TiO_2	—	—	4.00	—	5.00	5.00	—	14.00	20.00	20.00	15.00	15.00	5.00
ZrO_2	—	—	—	—	—	—	5.00	—	—	—	—	—	—
Li_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	3	4	4	4	4	4	5	4	5	5	4	4	4
Specific gravity (g/cc)	2.72	2.72	2.82	3.17	3.26	3.11	3.43	2.97	3.11	3.04	2.97	3.23	3.10
Young's modulus (GPa)	108.8	107.4	108.4	119.9	125.1	118.9	126.8	113.5	119.5	120.0	116.5	123.9	124.5
Specific elastic modulus (10^6Nm/kg)	40	39.5	38.4	37.8	38.4	38.2	37.00	38.2	38.4	39.5	39.2	38.3	40.2
Transition temperature (℃)	778	769	738	757	752	750	764	722	709	725	717	737	760
h=0.43 Deflexion (μm)	1.18	1.19	1.22	1.23	1.20	1.22	1.26	1.22	1.21	1.19	1.20	1.21	1.16

Table 2

(molar %)

Example	14	15	16	17	18	19	20	21	22	23	24	25	26
SiO_2	40.00	35.00	40.00	45.00	50.00	35.00	40.00	40.00	40.00	40.00	35.00	40.00	45.00
Al_2O_3	25.00	15.00	15.00	15.00	15.00	25.00	15.00	20.00	20.00	20.00	33.00	30.00	25.00
MgO	15.00	15.00	15.00	15.00	15.00	15.00	25.00	25.00	20.00	15.00	7.00	7.00	15.00
CaO	10.00	20.00	20.00	—	20.00	20.00	10.00	5.00	10.00	15.00	18.00	13.00	10.00
Y_2O_3	5.00	—	—	—	—	5.00	5.00	5.00	5.00	5.00	5.00	5.00	—
TiO_2	5.00	15.00	10.00	5.00	—	10.00	5.00	5.00	5.00	5.00	2.00	5.00	5.00
ZrO_2	—	—	—	—	—	—	—	—	—	—	—	—	—
Li_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	4	5	4	4	4	5	4	4	4	4	4	5	4
Specific gravity (g/cc)	3.06	2.99	2.91	2.83	2.75	3.15	3.14	3.10	3.11	3.12	3.045	3.04	2.78
Young's modulus (GPa)	118.3	113.4	109.2	105.1	101.9	122.5	119.4	121.7	119.0	117.0	116.4	116.1	109.7
Specific elastic modulus (10^6Nm/kg)	38.6	37.9	37.5	37.1	37.1	38.9	38.1	39.3	38.3	37.5	38.2	38.2	39.5
Transition temperature (℃)	767	724	730	742	753	761	751	757	763	787	803	795	775
h=0.43 Deflexion (μm)	1.21	1.23	1.25	1.27	1.27	1.20	1.22	1.18	1.22	1.24	1.22	1.23	1.19

Table 3

(molar %)

Example	27	28	29	30	31	32	33	34	35	36	37	38	39
SiO_2	45.00	45.00	42.00	43.00	45.00	41.00	40.00	40.00	35.00	40.00	37.00	36.00	36.50
Al_2O_3	25.00	25.00	28.00	25.00	25.00	27.00	27.00	32.00	33.00	32.00	35.00	35.00	33.00
MgO	12.00	10.00	8.00	15.00	22.00	20.00	17.00	17.00	—	—	—	—	—
CaO	10.00	10.00	15.00	10.00	—	—	—	—	25.00	20.00	16.00	19.00	22.00
Y_2O_3	—	—	3.50	—	1.00	4.00	8.00	8.00	5.00	8.00	5.00	5.00	4.00
TiO_2	8.00	5.00	3.50	5.00	7.00	8.00	8.00	3.00	2.00	—	—	—	2.00
ZrO_2	—	—	—	2.00	—	—	—	—	—	—	—	—	—
Li_2O	—	5.00	—	—	—	—	—	—	—	—	7.00	5.00	2.50
Surface roughness Ra (Å)	5	4	3	4	3	4	4	4	4	4	5	4	4
Specific gravity (g/cc)	2.795	2.724	2.952	2.841	2.836	3.024	3.218	3.167	3.028	3.114	2.933	2.963	2.952
Young's modulus (GPa)	109.7	107.4	118.5	112.0	116.0	123.1	127.3	127.4	112.4	116.0	113.0	112.4	112.1
Specific elastic modulus (10^6Nm/kg)	39.2	39.4	40.1	39.5	40.8	40.8	39.5	40.2	37.1	37.2	38.6	38.3	38.0
Transition temperature (℃)	760	700	786	767	769	778	778	802	828	844	742	758	771
h=0.43 Deflexion (μm)	1.20	1.20	1.17	1.19	1.15	1.15	1.18	1.16	1.26	1.25	1.22	1.23	1.24

Table 4

(molar %)

Example	40	41	42	43	44	45	46	47	48	49	50	51	52
SiO_2	38.00	35.00	43.00	41.00	40.00	40.00	44.00	40.00	40.00	44.00	44.00	44.00	40.00
Al_2O_3	32.00	37.00	30.00	30.00	25.00	30.00	25.00	15.00	12.50	20.00	15.00	10.00	15.00
MgO	—	—	17.00	18.00	25.00	20.00	25.00	30.00	30.00	30.00	35.00	40.00	35.00
CaO	15.00	10.00	—	—	—	—	—	—	—	—	—	—	—
Y_2O_3	5.00	8.00	6.00	7.00	5.00	5.00	1.00	10.00	12.50	1.00	1.00	1.00	5.00
TiO_2	—	—	4.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
ZrO_2	—	—	—	—	—	—	—	—	—	—	—	—	—
Li_2O	10.00	10.00	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	4	5	4	4	4	4	4	4	4	3	3	4	3
Specific gravity (g/cc)	2.905	3.022	3.071	3.14	3.063	3.057	2.833	3.386	3.515	2.85	2.87	2.89	3.119
Young's modulus (GPa)	111.4	115.5	124.3	128.9	124.1	124.2	117	129.8	131.9	116.3	116.0	116.1	123.8
Specific elastic modulus (10^6Nm/kg)	38.3	38.2	40.5	41.1	40.5	40.6	41.3	38.3	37.5	40.8	40.6	40.2	39.7
Transition temperature (℃)	710	727	791	799	778	785	768	773	778	758	743	736	751
h=0.43 Deflexion (μm)	1.23	1.23	1.16	1.14	1.15	1.15	1.14	1.22	1.24	1.15	1.15	1.17	1.18

Table 5

(molar %)

Example	53	54	55	56	57	58	59	60	61	Comparative 1	Comparative 2
SiO_2	40.00	40.00	40.00	40.00	35.00	43.00	40.00	40.00	45.00	SiO_2: 73.0	SiO_2: 52.0
Al_2O_3	10.00	10.00	7.50	15.00	15.00	21.00	25.00	17.00	25.50	Al_2O_3: 0.6	Al_2O_3: 1.0
MgO	40.00	35.00	40.00	25.00	35.00	30.00	25.00	35.00	23.00	CaO: 7.0	CaO: 16.0
CaO	—	—	—	—	—	—	—	—	—	Na_2O: 9.0	Na_2O: 7.0
Y_2O_3	5.00	10.00	7.50	15.00	5.00	1.00	5.00	3.00	3.00	K_2O: 9.0	K_2O: 5.0
TiO_2	5.00	5.00	5.00	5.00	10.00	—	—	—	2.00	ZnO: 2.0	F:19.0
ZrO_2	—	—	—	—	—	5.00	5.00	5.00	2.00	As_2O_3: 0.2	-
Li_2O	—	—	—	—	—	—	—	—	—	—	-
Surface roughness Ra (Å)	4	3	4	4	5	4	5	4	4	12	25
Specific gravity (g/cc)	3.166	3.411	3.35	3.604	3.225	2.952	3.152	3.110	2.97	2.60	2.60
Young's modulus (GPa)	125.6	129.6	128.5	134.0	129.5	120.0	126.4	124.7	126.5	79.0	91.0
Specific elastic modulus (10^6Nm/kg)	39.7	38.0	38.4	37.2	40.2	40.7	40.1	40.1	42.6	30.3	35.0
Transition temperature (℃)	752	765	755	790	746	771	779	763	791	554	-
h=0.43 Deflexion (μm)	1.18	1.22	1.21	1.25	1.16	1.15	1.17	1.16	1.09	—	-

Table 6

(molar %)

Example	100	101	102	103	104	105	106	107	108	109	110	111	112	
SiO_2	45.00	45. 00	45.00	45.00	45.00	40.00	44.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Al_2O_3	12.50	12.50	12.00	18.00	22.00	25.00	15.00	15.00	17.50	20.00	22.50	20.00	15.00	17.50
MgO	30.00	26.00	28.00	22.00	18.00	20.00	25.00	25.00	22.50	20.00	17.50	22.00	27.00	27.50
Y_2O_3	12.50	12.50	10.00	10.00	10.00	10.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	10.00
TiO_2		4.00					4.00							
ZrO_2			5.00	5.00	5.00	5.00		8.00	8.00	8.00	8.00	6.00	6.00	5.00
Li_2O														
CaO														
ZnO														
NiO														
Fe_2O_3														
R_2O_3														
Young's modulus (GPa)	130.2	129.0	130.0	129.1	129.9	131.0	129.5	133.0	133.3	132.4	132.3	132.6	133.5	131.0
Tg (℃)	790	773	794	771	812	806	784	773	778	775	795	783	773	773
Surface roughness Ra (Å)	4	3	4	4	4	4	3	3	4	3	4	4	4	4

Table 7

(molar %)

Example	114	115	116	117	118	119	120	121	122	123	124	125	126
SiO_2	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	42.00	42.00	42.00	42.00	40.00
Al_2O_3	22.50	25.00	25.00	20.00	15.00	15.00	20.00	25.00	25.00	20.00	15.00	20.00	22.50
MgO	22.50	20.00	17.50	22.50	27.50	25.00	20.00	15.00	18.00	23.00	25.00	20.00	22.50
Y_2O_3	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	8.00
TiO_2	5.00	5.00	7.50	7.50	7.50	10.00	10.00	10.00	5.00	5.00	8.00	8.00	7.00
ZrO_2													
Li_2O													
CaO													
ZnO													
NiO													
Fe_2O_3													
R_2O_3													
Young's modulus (GPa)	130.4	130.5	131.0	130.9	131.7	132.0	131.2	131.2	128.8	129.2	130.2	129.5	129.1
Transition temperature (℃)	792	801	782	780	776	772	779	795	791	791	777	785	795
Surface roughness Ra (Å)	4	3	3	4	4	3	3	3	3	4	3	3	4

Table 8

(molar %)

Example	127	128	129	130	131	132	133	134	135	136	137	138	139
SiO_2	40.00	40.00	40.00	45.00	50.00	45.00	50.00	42.00	42.00	40.00	42.00	42.00	42.00
Al_2O_3	17.50	17.50	22.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
MgO	27.50	24.50	19.50	22.50	22.50	17.50	17.50	17.50	15.50	17.50	12.50	10.50	20.00
Y_2O_3	8.00	8.00	8.00	10.00	10.00	10.00	10.00	10.00	12.00	10.00	10.00	12.00	10.00
TiO_2	7.00	10.00	10.00	5.00		5.00		8.00	8.00	10.00	8.00	8.00	8.00
ZrO_2													
Li_2O						5.00	5.00	5.00	5.00	5.00	10.00	10.00	2.50
CaO													
ZnO													
NiO													
Fe_2O_3													
R_2O_3													
Young's modulus (GPa)	129.6	129.7	129.5	127.1	122.2	125.9	121.5	128.6	130.5	130.3	124.1	125.8	130.4
Transition temperature (℃)	790	760	782	778	782	704	716	716	710	706	657	652	727
Surface roughness Ra (Å)	4	3	4	2	2	3	2	3	3	3	3	4	3

Table 9

(molar %)

Example	140	141	142	143	144	145	146	147	148	149	150	151	152
SiO_2	42.00	45.00	42.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Al_2O_3	17.50	15.50	17.50	23.00	23.00	23.00	23.00	23.00	23.00	28.00	18.00	13.00	8.00
MgO	18.50	17.50	20.50		5.00	10.00	15.00	20.00	25.00	10.00	20.00	25.00	30.00
Y_2O_3	14.00	12.00	10.00	25.00	20.00	15.00	10.00	5.00		10.00	10.00	10.00	10.00
TiO_2	8.00	5.00	10.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
ZrO_2													
Li_2O		5.00											
CaO													
ZnO													
NiO													
Fe_2O_3													
R_2O_3													
Young's modulus (GPa)	132.6	129.0	132.1	134.1	133.1	130.2	126.8	122.4	116	126.9	127	128.2	129.1
Transition temperature (℃)	797	715	767	816	837	815	801	781	753	815	786	778	775
Surface roughness Ra (Å)	3	3	4	4	4	4	4	4	4	3	3	3	4

Table 10

(molar %)

Example	153	154	155	156	157	158	159	160	161	162	163
SiO_2	45.00	45.00	45.00	45.00	38.00	38.00	38.00	40.00	38.00	38.00	38.00
Al_2O_3	13.00	23.00	4.00	32.00	15.50	20.00	15.50	17.50	22.50	20.00	17.50
MgO	20.00	20.00	34.00	6.00	24.50	20.00	22.50	20.50	17.50	18.00	20.50
Y_2O_3	15.00	5.00	10.00	10.00	12.00	12.00	12.00	10.00	12.00	12.00	12.00
TiO_2	7.00	7.00	7.00	7.00	10.00	10.00	12.00	12.00	10.00	12.00	12.00
ZrO_2											
Li_2O											
CaO											
ZnO											
NiO											
Fe_2O_3											
R_2O_3											
Young's modulus (GPa)	132.2	122.4	129.1	129.3	135.2	134.2	135.4	132.1	133.9	135.0	135.1
Transition temperature (℃)	797	768	767	812	780	786	774	775	792	778	779
Surface roughness Ra (Å)	4	4	4	4	4	4	3	4	4	4	4

Table 11

(molar %)

Example	164	165	166	167	168	169	170	171	172	173
SiO_2	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Al_2O_3	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
MgO	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
Nd_2O_3										10.00
TiO_2	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Yb_2O_3	10.00									
Tm_2O_3		10.00								
Er_2O_3			10.00							
Ho_2O_3				10.00						
Dy_2O_3					10.00					
Tb_2O_3						10.00				
Gd_2O_3							10.00			
Eu_2O_3								10.00		
Sm_2O_3									10.00	
Young's modulus (GPa)	128.4	128.0	127.7	127.4	126.0	125.3	125.2	123.2	122.4	120
Transition temperature (℃)	784	781	788	781	781	776	778	772	774	769
Surface roughness Ra (Å)	4	4	4	4	4	4	4	4	4	4

Table 12

(molar %)

Example	174	175	176	177	178	179	180	181	182	183	184	185	186
SiO_2	45.00	45.00	42.00	42.00	42.00	42.00	42.00	42.00	40.00	40.00	40.00	40.00	45.00
Al_2O_3	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50	10.00
MgO	22.50	22.50	17.50	12.50	17.50	12.50	17.50	12.50	19.50	20.50	22.50	17.50	20.00
Y_2O_3			10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
TiO_2	5.00	5.00	8.00	8.00	8.00	8.00	8.00	8.00	10.00	7.00	5.00	10.00	10.00
ZrO_2										5.00	5.00	5.00	
Li_2O													5.00
CaO			5.00	10.00									
ZnO							5.00	10.00					
NiO					5.00	10.00							
Fe_2O_3									5.00				
Pr_2O_3	10.00												
La_2O_3		10.00											
Young's modulus (GPa)	119.0	117.0	126.4	123.4	132.3	134.5	129.3	128.8	130.6	131.0	130.8	131.02	128.4
Transition temperature (℃)	763	773	777	778	776	776	765	754	761	776	784	784	692
Surface roughness Ra (Å)	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 13

(molar %)

Example	187	188	189	190	Comparative 1	Comparative 2
SiO_2	45.00	45.00	45.00	45.00	SiO_2:73.00	SiO_2:52.00
Al_2O_3	5.00	5.00	3.00	8.00	Al_2O_3:0.60	Al_2O_3:1.00
MgO	25.00	25.00	25.00	30.00	CaO:7.00	CaO:16.00
Y_2O_3	10.00	10.00	10.00	2.50	Na_2O:9.00	Na_2O:7.00
TiO_2	10.00	8.00	12.00	7.00	K_2O:9.00	K_2O:5.00
ZrO_2					ZnO:2.00	F:19.00
Li_2O	5.00	7.00	5.00	7.50	As_2O_3:0.20	
CaO						
ZnO						
NiO						
Fe_2O_3						
Pr_2O_3						
La_2O_3						
Young's modulus (GPa)	131.5	131.1	132.5	119.1	79.0	91.0
Transition temperature (℃)	687	664	687	652	554	
Surface roughness Ra (Å)	4	4	4	4	12.00	25

Table 14

(molar %)

Example	200	201	202	203	204	205	206	207	208	209
SiO_2	40.00	40.00	40.00	40.00	35.00	45.00	44.00	45.00	40.00	43.00
Al_2O_3	15.00	20.00	25.00	25.00	15.00	25.00	25.00	25.00	25.00	25.00
MgO	25.00	25.00	25.00	15.00	35.00	25.00	25.00	23.00	25.00	15.00
CaO	10.00	5.00		10.00						10.00
Y_2O_3	5.00	5.00	5.00	5.00	5.00		1.00	4.00	5.00	
TiO_2	5.00	5.00	5.00	10.00	10.00	5.00	5.00			5.00
ZrO_2								2.00	5.00	2.00
Li_2O								2.00		
Surface roughness Ra(Å)	4	4	4	4	5	4	4	4	5	4
Specific gravity (g/cm^3)	3.14	3.1	3.063	3.06	3.225	2.81	2.833	2.970	3.152	2.841
Young's modulus (GPa)	119.4	121.7	124.3	118.3	128.6	113.4	117.0	126.5	126.4	112.0
Specific elastic (10^6Nm/kg)	38.1	39.3	40.5	38.6	39.9	40.4	41.3	42.6	40.1	39.5

As seen from the results shown in Tables 1-14, the glasses of Examples 1-61, 100-190 and 200-209 have a high glass transition temperature and hence have sufficiently high heat resistance enough to bear desired heat treatment (usually at a temperature of 700°C or lower). In particular, they exhibits high glass strength characteristics such as Young's modulus and/or specific elastic modulus. Therefore, when they are used as substrates for magnetic recording

media, they are not likely to exhibit warp or walking even when they are rotated at a high speed, and hence they can meet the demand of further thinner substrates. In addition, they can have so excellent flatness as to be polished to a surface roughness (Ra) of 5Å or less, and therefore they can realize smaller flying height. Furthermore, the glasses of Examples 1-61 also exhibit reduced deflection. Therefore, the glasses of the present invention are useful as glass substrates for magnetic recording media.

On the other hand, while the chemically tempered glass substrate of Comparative Example 1 is excellent in surface smoothness and flatness, it is substantially inferior to the glass substrates of the present invention in heat resistance and strength characteristics such as specific elastic modulus. Therefore, when it is used for producing magnetic recording media, it cannot be subjected to sufficient heat treatment for the magnetic layer to obtain high coercive force and hence magnetic recording media having high coercive force cannot be provided. Moreover, such a glass having a low specific elastic modulus of around 30 x 10^6 Nm/kg suffers severe warp and deflection when it is made into substrates and therefore it cannot be used for thinner substrates.

The crystallized glass substrate of Comparative Example 2 is significantly inferior to the glasses of the present invention as to specific elastic modulus and surface smoothness. In particular, the surface smoothness of the substrate is degraded by relatively large crystal particles and hence higher recording density cannot be achieved.

The glasses of the present invention have high Young's modulus, high specific elastic modulus and high heat resistance, and therefore they are extremely useful as substrates for magnetic discs.

Method for producing hard disc

As shown in Fig. 1, a magnetic disc 1 comprises a glass substrate 2 made of the glass of the above Example 1, on which unevenness control layer 3, underlying layer 4, magnetic layer 5, protective layer 6 and lubricating layer 7 are provided in this order.

Each layer will be explained in detail. The substrate 1 was a disc having an outer circular periphery radius of 32.5 mm, inner circular periphery radius of 10.0 mm and thickness of 0.43 mm, whose main surfaces were subjected to precision polishing so that they should have surface roughness Ra of 4 Å and Rmax of 40Å.

The unevenness control layer is a thin AlN layer of 5-35% nitrogen content having average roughness of 50Å and surface roughness Rmax of 150Å.

The underlying layer is a thin layer of CrV composed of Cr: 83 at% and V: 17 at% having a thickness of about 600Å.

The magnetic layer is a thin layer of CoPtCr composed of Co: 76 at%, Pt: 6.6 at%, Cr: 17.4 at% having a thickness of about 300Å.

The protective layer is a carbon thin layer having a thickness of about 100Å.

The lubricating layer is a layer having a thickness of 8Å, which was formed by applying perfluoropolyether on the carbon protective layer by spin coating.

The method for producing magnetic discs will be explained hereinafter.

The glass of Example 1 was cut into a disc having an outer circular periphery radius of 32.5 mm, inner circular periphery radius of 10.0 mm and thickness of 0.5 mm and the both main surfaces were subjected to precision polishing so that they should have surface roughness Ra of 4Å and Rmax of 40Å to afford a glass substrate for magnetic discs.

Subsequently, the above glass substrate was placed on a substrate holder and transferred into a charging chamber of inline sputtering apparatus. Then, the holder on which the glass substrate was placed was transferred to a first chamber where an Al target was etched and sputtering was performed at a pressure of 4 mtorr and substrate temperature of 350°C in an atmosphere of Ar + N_2 gas (N_2 = 4%). As a result, an AlN thin layer having surface roughness Rmax of 150Å and thickness of 50Å (unevenness forming layer) was provided on the glass substrate.

The holder on which the glass substrate having the formed AlN layer was placed was then serially transferred into a second chamber provided with a CrV target (Cr: 83 at%, V: 17 at%) and a third chamber provided with a CoPtCr target (Co: 76 at%, Pt: 6.6 at%, Cr: 17.4 at%) successively, and thin layers were formed on the substrate. Sputtering was performed at a pressure of 2 mtorr and substrate temperature of 350°C in an Ar atmosphere, thereby a CrV underlying layer having a thickness of about 600 Å and CoPtCr magnetic layer having a thickness of about 300 Å were formed.

The substrate having the formed unevenness control layer, underlying layer and magnetic layer was then transferred to a fourth chamber provided with a heater for heat treatment. The fourth chamber had an inner atmosphere of Ar gas ((pressure: 2 mtorr) and the heat treatment was performed.

The substrate was then transferred into a fifth chamber provided with a carbon target, and a carbon protective layer having a thickness of about 100Å was formed under the same condition as used for forming of the CrV underlying layer and the CoPtCr magnetic layer except that the layer was formed in an atmosphere of Ar + H_2 gas (H_2 = 6%).

Finally, the substrate after forming the carbon protective layer was taken out from the above inline sputtering apparatus, and a lubricating layer having a thickness of 8 Å was formed by applying perfluoropolyether on the carbon protective layer by dipping to produce a magnetic disc.

The present invention was explained by referring to the preferred examples, but the present invention is not limited

to the above examples.

Utility in Industry

By using glass of the present invention, a glass substrate having high specific elastic modulus of 36 x 10^6 Nm/kg or more or high Young's modulus of 110 GPa or more, high transition temperature of 700°C or higher (high heat resistance), excellent surface smoothness (surface roughness Ra < 9Å) and high strength can be provided. Because the glass of the present invention has excellent heat resistance, it can be subjected to heat treatment necessary for improving magnetic layer characteristics without causing deformation of substrates made from it. Therefore, it can have excellent flatness and hence achieve smaller flying height of magnetic head, i.e., higher recording density. Moreover, it exhibits high specific elastic modulus and high strength, it can realize thinner magnetic discs and prevent breakdown of magnetic discs. Furthermore, it can be stably obtained as glass and easily produced in an industrial scale. Therefore, it can be surely expected to be used as economical glass for substrates of next generation magnetic recording media.

Claims

1. Glass for substrates having a specific elastic modulus G of 36 x 10^6 Nm/kg or more.

2. The glass of claim 1 whose surface roughness (Ra) can be made 9Å or less.

3. The glass of claim 1 which has a transition temperature of 700°C or higher.

4. Glass having a composition of , as oxides constituting the glass, SiO_2: 25-52%, Al_2O_3: 5-35%, MgO: 15-45%, Y_2O_3: 0-17%, TiO_2: 0-25%, ZrO_2: 0-8%, CaO: 1-30%, provided that Y_2O_3+ TiO_2 + ZrO_2 + CaO: 5-30% and B_2O_3 + P_2O_5: 0-5%, in molar %, and having a specific elastic modulus of 36 x 10^6 Nm/kg or more.

5. The glass of claim 4 further containing As_2O_3 + Sb_2O_3: 0-3% and ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3+ P_2O_5+V_2O_5: 0-5%.

6. Glass having a composition of, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 10-37%, MgO: 5-40%, TiO_2: 1-25%, in molar %, and having a specific elastic modulus of 36 x 10^6 Nm/kg or more.

7. The glass of claim 6 further containing Y_2O_3: 0-17%, ZrO_2: 0-8%, CaO: 0-25%, As_2O_3+ Sb_2O_3: 0-3% and ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5: 0-5%.

8. Glass having a composition containing, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 20-40%, CaO: 8-30%, Y_2O_3: 2-15%, in molar %, and having a specific elastic modulus of 36 x 10^6 Nm/kg or more.

9. The glass of claim 8 further containing MgO: 0-20 %, TiO_2: 0-25%, Li_2O: 0-12%, As_2O_3+ Sb_2O_3: 0-3% and ZnO + SrO + NiO + CoO + FeO + CuO +Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5: 0-5%.

10. The glass of any of claims 1-9 wherein the glass exhibits a Young's modulus of 110 GPa or more.

11. Glass for substrates wherein the glass exhibits a Young's modulus of 110 GPa or more.

12. The glass of claim 11 whose surface roughness (Ra) can be made 9Å or less.

13. The glass of claim 11 or 12 having a transition temperature of 700°C or higher.

14. Glass having a composition containing, as oxides constituting the glass, SiO_2: 30-60%, Al_2O_3: 0-35%, MgO: 0-40%, Li_2O: 0-20%, Y_2O_3: 0-27%, La_2O_3: 0-27%, CeO_2: 0-27%, Pr_2O_3: 0-27%, Nd_2O_3: 0-27%, Sm_2O_3: 0-27%, Eu_2O_3: 0-27%, Gd_2O_3: 0-27%, Tb_2O_3: 0-27%, Dy_2O_3: 0-27%, Ho_2O_3: 0-27%, Er_2O_3: 0-27%, Tm_2O_3: 0-27%, Yb_2O_3: 0-27%, provided that Y_2O_3 + La_2O_3 + CeO_2 + Pr_2O_3 + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_2O_3 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3: 1-27% and Li_2O + MgO + Y_2O_3 + La_2O_3 + CeO_2 + Pr_2O_3 + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_2O_3 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3 > 25%, in molar %, and having a Young's modulus of 110 GPa or more.

15. The glass of claim 14 further containing TiO_2: 0-20%, ZrO_2: 0-8%, provided that TiO_2 + ZrO_2: 0-20%, CaO: 0-15%,

ZnO: 0-15%, NiO: 0-15% and Fe_2O_3: 0-15%, provided that CaO + ZnO + NiO + Fe_2O_3: 0-15 %.

16. The glass of claim 14 or 15 further containing As_2O_3+ Sb_2O_3: 0-2%, B_2O_3 + P_2O_5 + Nb_2O_5 + V_2O_5 + Cr_2O_3 + Ga_2O_3 + CoO + SrO + BaO + FeO + CuO + MnO + Na_2O + K_2O: 0-8%.

17. The glass of any of claims 14-16 wherein the glass exhibits a specific elastic modulus G of 36 x 10^6 Nm/kg or more.

18. The glass of any of claims 1-17 which is glass for substrates of magnetic discs.

19. A material which is used for a substrate of information recording media and consists of SiO_2-Al_2O_3-RO glass wherein R is a covalent metal which is characterized in that said glass contains 20 molar % or more of Al_2O_3.

20. A material which is used for a substrate of information recording media and consists of SiO_2-Al_2O_3-RO glass wherein R is a covalent metal which is characterized in that said glass contains 20 molar % or more MgO as RO.

21. A material which is used for a substrate of information recording media and consist of SiO_2-Al_2O_3-RO glass wherein R is a covalent metal which is characterized in that said glass further contains Y_2O_3.

22. The material of claim 21 which contains 0.5-17 molar % of Y_2O_3.

23. The material of any of claims 19-22 which contains at least one of TiO_2 and ZrO_2.

24. A substrate for information recording media characterized in that said substrate consists of material of any of claims 19-23.

25. Glass used for information recording media characterized in that said glass contains one or more than two metal oxides which are selected form the group consisting of Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, Y, Zr, Nb, Mo, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Hf, Ta, and W in the range of 3-30 molar %.

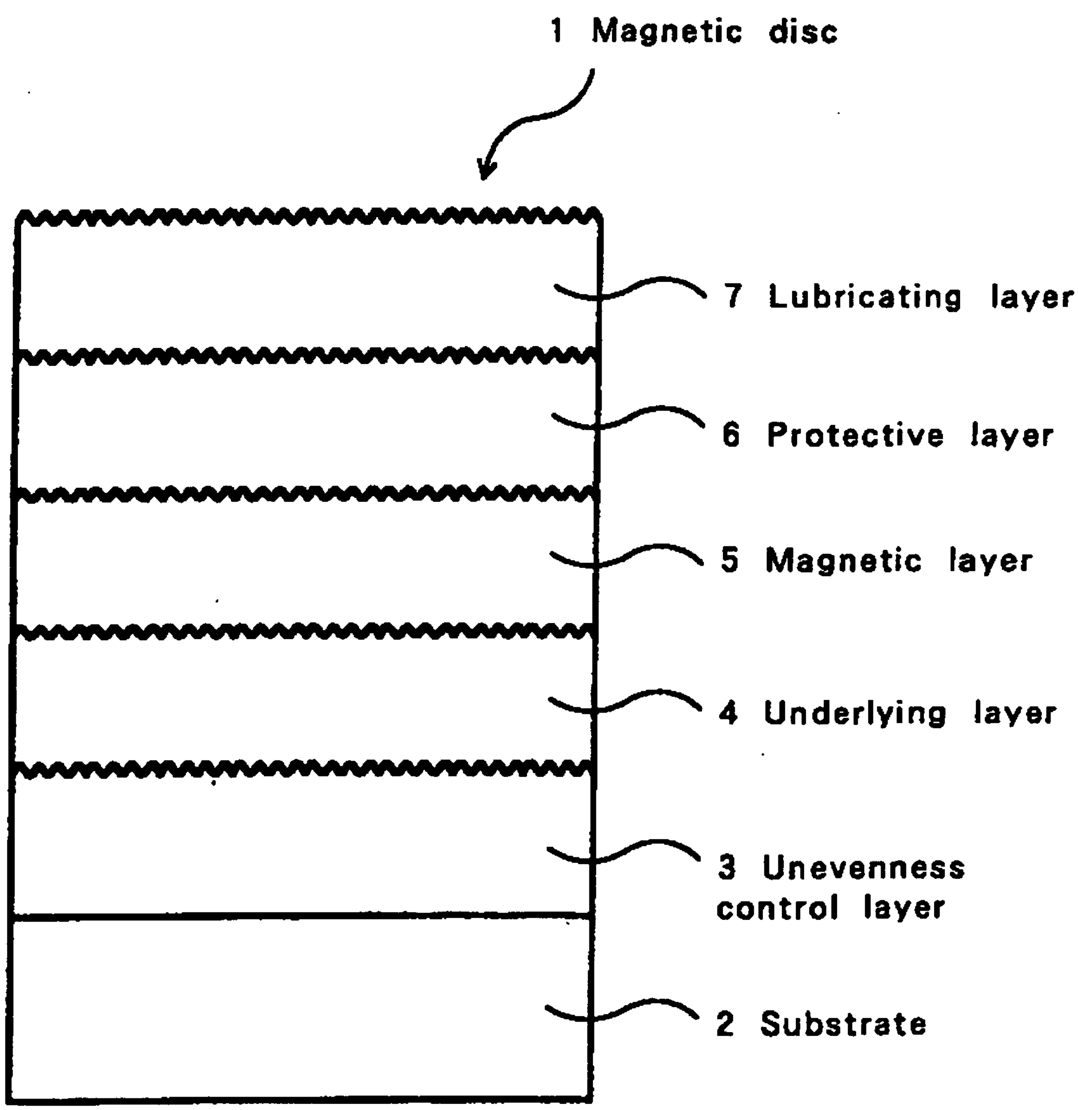
26. The glass of claim 24 wherein Young's modulus of the glass is 90 GPa or more.

27. A substrate used for information recording media characterized in that said substrate consists of the glass of claim 25 or 26.

28. A substrate of claim 24 or 27 wherein the information recording media are magnetic discs.

29. A magnetic disc characterized in that said disc has at least a magnetic layer on the substrate of claim 28.

Fig. 1


1 Magnetic disc
7 Lubricating layer
6 Protective layer
5 Magnetic layer
4 Underlying layer
3 Unevenness control layer
2 Substrate

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/03099

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl[6] C03C3/068, C03C3/108

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl[6] C03C3/062-3/118, 10/00-10/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Kokai Jitsuyo Shinan Koho 1971 - 1997
Toroku Jitsuyo Shinan Koho 1994 - 1997
Jitsuyo Shinan Toroku Koho 1996 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP, 710627, A1 (Corning Inc.), May 8, 1996 (08. 05. 96), Claims & US, 5476821, A & JP, 9-77531, A	1 - 29
Y	JP, 8-169724, A (Ohara & Co., Ltd.), July 2, 1996 (02. 07. 96), Claims (Family: none)	1 - 29
Y	JP, 7-300340, A (Ohara & Co., Ltd.), November 14, 1995 (14. 11. 95), Claims & US, 5561089, A	1 - 29
Y	JP, 7-291660, A (Ohara & Co., Ltd.), November 7, 1995 (07. 11. 95), Claims; page 3, right column, lines 1 to 18 & US, 5532194, A	1 - 29
Y	JP, 7-247138, A (Ohara & Co., Ltd.), September 26, 1995 (26. 09. 95), Claims (Family: none)	1 - 29

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search December 3, 1997 (03. 12. 97)	Date of mailing of the international search report December 16, 1997 (16. 12. 97)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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WO 98/009922 (12.03.1998 Gazette 1998/10)

(54) GLASS FOR INFORMATION RECORDING MEDIUM SUBSTRATE AND GLASS SUBSTRATE

GLAS FÜR INFORMATIONS AUF ZEICHNUNGSTRÄGERSUBSTRAT UND GLASSUBSTRAT

VERRE POUR SUBSTRAT D'ENREGISTREMENT D'INFORMATIONS ET SUBSTRAT DE VERRE

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(73) Proprietor: **HOYA CORPORATION**
Shinjuku-ku Tokyo 161 (JP)

(72) Inventors:
- **ZOU, Xuelu, Hoya Corporation**
Tokyo 161 (JP)
- **TORATANI, Hisayoshi, Hoya Corporation**
Tokyo 161 (JP)

(74) Representative: **Godemeyer, Thomas, Dr.**
Sternagel, Fleischer, Godemeyer & Partner
Patentanwälte
An den Gärten 7
51491 Overath (DE)

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JP-A- 8 169 724
JP-A- 7 247 138
JP-A- 7 300 340

EP 0 858 974 B1

Description

Field of the Invention

[0001] The present invention relates to glass and glass substrate suitably used for substrates of information recording media such as magnetic discs and optical discs, heat resistant substrates of low temperature polycrystalline silicon liquid crystal display devices, which are expected as next generation LCDs, substrates for various electric and electronic components and the like. In particular, it relates to glass suitable for substrates of information recording media and the like, which exhibits high specific elastic modulus and/or Young's modulus and high heat resistance and, when used as a substrate, realizes excellent surface smoothness.

Description of the Related Art

[0002] Major components of magnetic storage devices cf electronic computers and the like are a magnetic recording medium and a magnetic head for reconstruction of magnetically recorded information. Flexible discs and hard disks have been known as magnetic recording media. As substrates for hard discs (magnetic discs), for example, aluminum substrates, glass substrates, ceramic substrates, carbon substrates and the like have been known. In practical use, however, an aluminum substrate or a glass substrate is mainly used according to the intended size and the use thereof.

[0003] Recently, flying height of magnetic heads is markedly reduced as hard disc drivers for notebook personal computers are made smaller and their magnetic recording density made higher. Accordingly, extremely high precision has been demanded for the surface smoothness of magnetic disc substrates.

[0004] However, it is difficult to produce smooth surface more than a certain level of precision with an aluminum alloy. That is, even though it is polished by using highly precise abrasives and processing apparatuses, the polished surface may suffer from plastic deformation because of the low hardness of the alloy. Even if the aluminum alloy is plated with nickel-phosphorous, the surface roughness Ra cannot be made 2 nm (20Å) (angstrom) or less. In addition, as hard disk drivers are made smaller and thinner, a further smaller thickness of substrates for magnetic discs is also strongly desired. However, it is difficult to produce such a thin disc with an aluminum alloy having a certain strength defined by specification of hard disk drivers because of low strength and stiffness of aluminum alloy.

[0005] Therefore, glass substrates for magnetic discs having high strength, high stiffness, high impact resistance and high surface smoothness have been developed. Because glass substrates have excellent surface smoothness and mechanical strength, they have been paid much attention as substrates for present and future use. For example, as such glass substrates, chemically tempered glass substrates whose surfaces are strengthened by the ion exchange technique, crystallized glass substrates subjected to crystallization treatment, alkali-free glass substrates which do not substantially contain alkaline substances and the like have been known well.

[0006] For example, as a chemically tempered glass substrate, Japanese Patent Unexamined Publication No. Hei 1-239036 (referred to as Reference 1 hereinafter) discloses a glass substrate for magnetic recording media strengthened by subjecting to ion exchange treatment a glass material for the substrate containing, indicated in terms of % by weight, 60-70% of SiO_2, 0.5-14 % of Al_2O_3, 10-32% of R_2O where R is an alkali metal, 1-15% of ZnO and 1.1-14% of B_2O_3.

[0007] As a crystallized glass, Japanese Patent Unexamined Publication No. Hei 7-187711 (referred to as Reference 2 hereinafter) discloses a glass substrate for magnetic recording media containing, indicated in terms of % by weight, 50-65% of SiO_2, 18-25% of CaO, 6-11% of Na_2O, 6-12% of K_2O, 0-2.5% of Al_2O_3 and 5-9% of F and containing kanasite as main crystals. U.S. Patent No. 5,391,522 (referred to as Reference 3 hereinafter) discloses a crystallized glass substrate for magnetic discs containing 65-83% of SiO_2, 8-13% of Li_2O, 0-7% of K_2O, 0.5-5.5% of MgO, 0-5% of ZnO, 0-5% of PbO, (provided that MgO + ZnO + PbO is 0.5-5%), 1-4% of P_2O_5, 0-7% of Al_2O_3 and 0-2% of As_2O_3 + Sb_2O_3 and containing microcrystalline particles of $Li_2O{\cdot}2SiO_2$ as main crystals.

[0008] As an alkali-free glass, Japanese Patent Unexamined Publication No. Hei 8-169724 (referred to as Reference 4 hereinafter) discloses a glass substrate for magnetic discs having a composition containing, indicated in terms of % by weight, 35-55% of SiO_2 + Al_2O_3, 0-10% of B_2O_3, 40-60% of CaO + BaO, provided that CaO $\geqq$ 5%, 0-10% of ZnO + SrO + MgO, 0-5% of TiO_2, 0-5% of ZrO_2, 0-1% of As_2O_3 and/or Sb_2O_3.

[0009] EP-A-0 710 627 describes a glass-ceramic material used for rigid disc substrates for use in magnetic memory disc devices. These glass-ceramic articles are prepared by heat treatment of precursor glass bodies.

[0010] Recent HDDs (hard disk drivers) have been required to have higher recording capacity to meet higher performance of personal computers, and a smaller and thinner disc substrate, smaller flying height of magnetic heads and higher revolution speed of discs have been required to meet smaller size and higher performance of personal computers. It is expected that the thickness of 6.35 cm (2.5-inch) diameter disc substrates should become thinner from the present thickness 0.635 mm to a thickness of 0.43 mm, or even 0.38 mm. In addition, for recent higher recording density of 8.89 cm (3.5)-inch hard discs for servers and higher data processing speed, requirement for stiffness of

substrate materials become increasingly severer, and conventional aluminum substrates seem to almost reach their limits of performance. It is expected that further higher capacity and smaller size of hard discs will be sought in future. Therefore, smaller thickness, higher strength, more excellent surface smoothness, higher impact resistance and the like of substrates for magnetic recording media will be further strongly demanded.

[0011] However, as disc substrates become thinner, they become more likely to suffer deflexion and warp. On the other hand, as higher recording density is sought, lower flying height of magnetic heads and higher revolution speed of magnetic discs are further sought yet, and such deflexion and warp of substrates may cause breakdown of magnetic discs. However, if thickness of conventional glass substrates is made thinner than currently used, the problems due to the deflexion and warp mentioned above will become unacceptably marked and thus thinner discs cannot be realized.

[0012] Degree of deflexion and warp of substrates can be evaluated from specific elastic modulus (= Young's modulus/specific gravity) or Young's modulus of substrate material. Materials of higher specific elastic modulus are required for suppressing the problems of the deflexion and warp of substrates made with a smaller thickness. Further, materials of higher Young's modulus are required for suppressing the problems of the deflexion of substrates to be rotated at a high speed.

[0013] The above situation may be further explained as follows. That is, with recent improvements on smaller size, higher capacity and higher speed of HDDs, it is expected that the thickness of 8.89 cm (3.5)-inch discs currently used of 0.8 mm will be made smaller to 0.635 mm, and 0.635 mm of current 6.35 cm (2.5)-inch discs to 0.43 mm, or even to 0.38 mm. Revolution speed of substrates is also expected to be made faster from the current maximum speed of 7200 rpm to 10000 rpm, or even to 14000 rpm. As substrates for such magnetic recording media become thinner, they become more likely to suffer deflexion, undulation and warp, and it is expected that, as the revolution speed becomes higher, stress loaded on the substrates (force exerted by wind pressure caused by rotation of discs) will become larger. Based on the theory of dynamics, the deflexion W of a disc receiving load of P per unit area is represented by the following formula:

$$W \propto \frac{Pa^4}{h^3 E}$$

wherein a represents an outer diameter of disc, h represents a thickness of substrate and E represents Young's modulus of disc material.

[0014] In static state, force loaded on the disc is the gravitation alone, and the deflexion W is represented by the following formula:

$$W \propto \frac{hda^4}{h^3 E} = \frac{da^4}{h^2 E} = \frac{a^4}{h^2 G}$$

wherein d represents a specific gravity of disc material and G is a specific elastic modulus of disc material (= Young's modulus/specific gravity).

[0015] On the other hand, supposing that the gravitational force is balanced by centrifugal force and can be ignored in rotating state of disc, force loaded on the disc may be considered only wind pressure caused by the rotation of the disc. The wind pressure is represented as a function of disc revolution speed and said to be proportional to the second power of the speed. Accordingly, the deflexion W when the disc is rotating in a high speed is represented by the following formula:

$$W \propto \frac{(rpm)^2 a^4}{h^3 E}$$

[0016] Therefore, in order to suppress the deflexion W of substrate to be rotated at a high speed, a material of high Young's modulus E is required. According to the present inventors' calculation, when the thickness of 6.35 cm (2.5)-inch substrate is made smaller from 0.635 mm to 0.43 mm, and the thickness of 3.5-inch substrate from 0.8 mm to 0.635 mm, a substrate material having a specific elastic modulus higher than that of conventional materials should be required. Further, when the current revolution speed of 8.89 cm (3.5)-inch high-end substrates of 7200 rpm is made faster to prospective 10000 rpm, an aluminum substrate having Young's modulus of around 70 GPa cannot meet such a high speed, and a new substrate material having a further higher Young's modulus should be required. As the specific elastic modulus or Young's modulus of substrate material becomes higher, not only stiffness of substrates becomes higher, but also impact resistance and strength of substrates become higher. Therefore, a glass material having high

specific elastic modulus [illegible]igh Young's modulus is strongly desired in the [illegible]f HDD production.

[0017] There are furthe[illegible]perties of substrates for magnetic recording medi[illegible]quired for realizing higher recording density other than the specific elastic modulus and Young's modulus. One of those is high heat resistance, and another is high surface smoothness. In order to obtain higher recording density of magnetic recording media, it is necessary to enhance magnetic characteristics such as magnetic coercive force of magnetic layer (magnetic recording layer). While coercive force of magnetic layer may vary depending on the kind of magnetic material used, coercive force of the magnetic material may be enhanced by heat-treatment even if the same material is used. Therefore, separating from development of new magnetic materials, it may be desirable to treat a magnetic layer formed on a substrate at a higher temperature in order to obtain higher coercive force using a conventional material. It is also possible to obtain higher recording density by making flying height of magnetic heads smaller. Therefore, the flying height of magnetic heads will be further made smaller in future. To realize smaller flying height of magnetic heads, good smoothness of disc surfaces and hence good smoothness of substrate surfaces are required.

[0018] The chemically tempered glass disclosed in Reference 1 has a glass transition point of around 500°C. However, to improve coercive force of magnetic layer, heat treatment at a temperature higher than 500°C is effective. Accordingly, heat resistance of the chemically tempered glass of Reference 1 itself is insufficient. Chemically tempered glasses are generally made by providing an ion exchanged layer with alkali metal ions on surfaces of the glasses. However, when a magnetic layer is formed on the surface of a chemically tempered glass and heat-treated, the ions in the ion exchanged layer may disadvantageously migrate to the magnetic layer and adversely affect it. The migration of the alkali metal ions to the magnetic layer is more activated as the temperature becomes higher. To suppress the migration of alkali metal ions, heat treatment at a lower temperature is desirable. Thus, when chemically tempered glass substrates are used, it is difficult to improve magnetic characteristics by heat treatment at a high temperature and it is difficult to obtain magnetic recording media having high coercive force. The above chemically tempered glass has a specific elastic modulus of about 30×10^6 Nm/kg and Young's modulus of about 80 GPa, and hence exhibits poor stiffness. Therefore, it cannot be used for 3.5-inch high-end disc substrates and thinner disc substrates. Moreover, chemically tempered glass substrates have stress layers on both surfaces, and these stress layers may cause deflexion when the stress layers do not have uniform and equivalent stress. Therefore, it is difficult to realize smaller flying height of magnetic heads and high-speed rotation with chemically tempered glass.

[0019] The conventional crystallized glasses such as those disclosed in References 2 and 3 exhibit excellent heat resistance because they do not show transition. However, glass substrates for magnetic recording media are required to have more excellent surface smoothness as higher recording density is attempted. This is because higher recording density of magnetic recording media requires a smaller flying height of magnetic heads. However, because crystallized glass contains many microparticles, they hardly afford substrates of a surface roughness (Ra) of 1 nm (10Å) or less. As a result, substrates have poor surface smoothness and surface configuration of discs is degraded. An unevenness control layer, for example, is formed on substrates to prevent a magnetic head from being absorbed to magnetic discs. However, it is difficult to control surface homology of such an unevenness control layer provided on a substrate of crystallized glass.

[0020] The alkali-free glass disclosed in Reference 4 has a high transition temperature as high as 730°C at most. However, it has a specific elastic modulus of only $27\text{-}34 \times 10^6$ Nm/kg and Young's modulus of around 70-90 GPa, and hence it can no way meet the demand of further thinner magnetic disc substrates.

[0021] As a substrate of excellent heat resistance, the carbon substrate disclosed in Japanese Patent Unexamined Publication No. Hei 3-273525 (referred to as Reference 5 hereinafter) can be mentioned. However, the carbon substrate has a specific elastic modulus of around $15\text{-}19 \times 10^6$ Nm/kg and hence it is inferior to glass in mechanical strength. Therefore, it can hardly meet the demand for a thinner substrate required for the production of smaller magnetic discs. In addition, carbon substrates have many surface defects and hence it is difficult to realize higher recording density with them.

[0022] Thus, no oxide glass which has high specific elastic modulus or Young's modulus, exhibits high heat resistance and excellent surface smoothness (surface roughness $\leqq$ 0.5 nm (5Å)) and can be produced in a large scale at low cost is currently found in the market. Even the SiO_2-Al_2O_3-MgO glasses, which is well known as commercially available oxide glass of high Young's modulus, have a Young's modulus of around 80-90 GPa at most.

[0023] Therefore, an object of the present invention is to provide a novel glass material satisfying high strength, high impact resistance, high specific elastic modulus, high heat -resistance and high surface smoothness required for the production of smaller and thinner substrates for information recording media of higher recording density in future.

[0024] More specifically, the object of the present invention is to provide a glass substrate having a specific elastic modulus of 36×10^6 Nm/kg or more and glass transition temperature of 700°C or higher, not containing microcrystalline particles, and exhibiting high surface smoothness (surface roughness Ra of 0.9 nm (9 Å) or less).

[0025] A further object of the present invention is to provide a glass substrate having a Young's modulus of 110 GPa or more, preferably a glass transition temperature of 700 °C or higher, not containing microcrystalline particles, and exhibiting high surface smoothness (surface roughness Ra of 0.9 nm (9Å) or less).

[0026] Degree of deflexion and warp of disc substrates can be estimated from specific elastic modulus (= Young's modulus/specific gravity) of the material composing the substrate. In order to suppress deflexion and warp of thinner substrates to the extent that such problems do not occur, materials with higher specific elastic modulus are required. However, in a certain glass composition, effects added to specific elastic modulus by glass components have not been well known.

[0027] An object of the present invention is to provide a novel glass exhibiting higher specific elastic modulus than those presently known by establishing theoretical relation between specific elastic modulus and glass composition, focussing on SiO_2-Al_2O_3-RO glasses (wherein R is a bivalent metal) which are preferred as substrates for information recording media such as magnetic discs, and investigating effects of glass components to specific elastic modulus.

[0028] A further object of the present invention is to provide substrates for information recording media using the above glass and information recording media using the above substrate.

SUMMARY OF THE INVENTION

[0029] Therefore, in order to provide glass materials having a specific elastic modulus G of 36×10^6 Nm/kg or more or a Young's modulus of 110 GPa or more, the present inventors have designed novel glass compositions based on the theoretical calculation suggested by themselves and conducted various experiments and researches. As a result, it was found that novel glass which has a high specific elastic modulus and/or high Young's modulus not obtained so far, excellent surface smoothness and high heat resistance and producible in a large scale at a low cost can be obtained by using components greatly contributing to the improvement of Young's modulus such as Al_2O_3, Y_2O_3, MgO, TiO_2 and rare earth metal oxides in a large amount. In addition, with respect to SiO_2-Al_2O_3-RO glasses, new glass materials exhibiting higher specific elastic modulus than those presently known have been found. Based on this finding, the present invention has been completed.

[0030] The present invention is described hereinafter.

[0031] Glass for substrates having a specific elastic modulus G of 36×10^6 Nm/kg or more (hereinafter referred to Glass (1)).

[0032] Glass containing, as oxides constituting the glass, SiO_2: 25-52%, Al_2O_3: 5-35%, MgO: 15-45%, Y_2O_3: 0-17%, TiO_2: 0-25%, ZrO_2; 0-8%, CaO: 1-30%, provided that $Y_2O_3 + TiO_2 + ZrO_2$ + CaO: 5-30% and $B_2O_3 + P_2O_5$: 0-5%, in molar %, and having a specific elastic modulus of 36×10^6 Nm/kg or more (hereinafter referred to Glass (2)).

[0033] Glass having a composition containing, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 10-37%, MgO: 5-40%, TiO_2: 1-25%, in molar %, and having a specific elastic modulus of 36×10^6 Nm/kg or more (hereinafter referred to Glass (3)).

[0034] Glass having a composition containing, as oxides constituting the glass, SiO_2: 25-50%, Al_2O_3: 20-40%, CaO: 8-30%, Y_2O_3: 2-15%, in molar %, and having a specific elastic modulus of 36×10^6 Nm/kg or more (hereinafter referred to Glass (4)).

[0035] A substrate for information recording media composed of the above glass material and a magnetic disc comprising said substrate and magnetic layer thereon.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036]

Fig. 1 is a schematic cross-sectional view of a magnetic disc 1 comprising a glass substrate 2, on which an unevenness control layer 3, underlying layer 4, magnetic layer 5, protective layer 6 and lubricating layer 7 are provided in this order.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0037] The present invention will be further explained hereinafter.

[0038] The term "glass" used in the present invention means glass which does not substantially contain crystal grains, and does not mean those called as crystallized glass or glass ceramics containing at least 20% of crystal grains.

Glass (1)

[0039] Glass (1) is a glass for substrate characterized in that it has a specific elastic modulus G of 36×10^6 Nm/kg or more.

[0040] When the specific elastic modulus G is less than 36×10^6 Nm/kg, a substrate made of the glass exhibits severe deflexion, and, for example, a substrate of such glass having a thickness of 0.43 mm or less required for

magnetic recording media discs of the next generation may exhibit a maximum deflexion of 1.4 µm or more. As a result, flying stability of magnetic heads cannot be obtained and hence reconstruction of recorded information cannot be performed stably. To obtain a substrate exhibiting a maximum deflexion of 1.25 µm or less, glass having a specific elastic modulus G of 37 × 10^6 Nm/kg or more is preferred. Glass having a specific elastic modulus of 42 × 10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflexion of 1.4 µm or less even if it is made as a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45 × 10^6 Nm/kg or less.

[0041] Glass (1) is glass whose surface roughness (Ra) can be made 0.9 nm (9Å) or less, in addition to having a specific elastic modulus G of 36 × 10^6 Nm/kg or more. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 0.9 nm (9Å) or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, glass whose surface roughness (Ra) can be made 0.5 nm (5Å) or less is preferred.

[0042] Glass (1) is glass having a transition temperature of 700°C or more, in addition to having a specific elastic modulus G of 36 × 10^6 Nm/kg or more and/or being possible to have surface roughness (Ra) of 0.9 nm (9 Å) or less. Because of a transition temperature of 700°C or higher, heat resistance of substrate higher than that of the conventional one can be obtained, in addition to the reduced deflexion. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

[0043] As specific examples of glass (1) having the above characteristics, glasses (2), (3) and (4) can be mentioned. These glasses are oxide glasses comprising cations having a small ionic radius, strong chemical bonding force and high packing density in the glass structure in order to satisfy the characteristics of glass (1).

Glass (2)

[0044] Glass (2) is a composition constituted mainly for obtaining a high specific elastic modulus, and has a specific elastic modulus G of 36 × 10^6 Nm/kg or more. A glass having specific elastic modulus G of 36 × 10^6 Nm/kg or more can afford a substrate exhibiting reduced deflexion. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it may exhibit a maximum deflexion of 1.4 µm or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be performed stably. To obtain a substrate exhibiting a maximum deflexion of 1.25 µm or less, glass having a specific elasticmodulus G of 37 × 10^6 Nm/kg or more is preferred. Glass having a specific elastic modulus of 42 × 10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflexion of 1.4 µm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45 × 10^6 Nm/kg or less.

[0045] Glass (2) can have a surface roughness (Ra) of 0.9 nm (9Å) or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 0.9 nm (9Å) or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 0.5 nm (5Å) or less is preferred.

[0046] Glass (2) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflexion, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

[0047] SiO_2 acts to form the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, oxide glass containing more than 52% of SiO_2 as a main component of the glass no longer exhibits a specific elastic modulus exceeding 36 × 10^6 Nm/kg, and therefore the content of SiO_2 is suitably 52% or less. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass, and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-52%, preferably in the range of 30-50%.

[0048] Al_2O_3 is very important as a component for imparting high heat resistance and high durability to glass and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, a content of Al_2O_3 less than 5% cannot sufficiently improve Young's modulus of glass. When the content of Al_2O_3 exceeds 35%, MgO, which is a

component contributing to improvement of specific elastic modulus of glass, cannot be introduced in a sufficient amount and hence melt characteristics of glass at a high temperature is also degraded. Therefore, the content of Al_2O_3 is suitably in the range of 5-35%, preferably in the range of 7-32%.

[0049] MgO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass. In particular, when the content of Al_2O_3 is less than 20%, it is preferred to introduce a large amount of MgO in order to maintain high specific elastic modulus of glass. However, sufficiently stable glass suitable for large scale production cannot be obtained with a MgO content exceeding 45%. On the other hand, if the content of MgO is less than 15%, Young's modulus of glass tends to be lowered. Therefore, the content of MgO is suitably in the range of 15-45%, preferably in the range of 22-40%.

[0050] Y_2O_3 is a component introduced for enhancing crystallization stability of glass and improving durability and melt characteristics of glass at a high temperature. In particular, introduction of a small amount of Y_2O_3 markedly contributes to enhancement of specific elastic modulus of glass and improvement of glass homogeneity. However, while Y_2O_3 improves Young's modulus of glass, too much amount of Y_2O_3 steeply increases the specific gravity of glass and hence disadvantageously tends to degrade the specific elastic modulus of the glass. Therefore, the content of Y_2O_3 is suitably 17% or less, preferably 15% or less. To obtain distinct effects of the addition of Y_2O_3, the content of Y_2O_3 is preferably 0.5% or more.

[0051] TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves melt characteristics of glass, enhances structure stability and improves durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. In particular, in glass containing large amounts of MgO, Al_2O_3 and the like, TiO_2 improves melt characteristics at a high temperature and crystallization stability of glass and is surely expected to enhance specific elastic modulus of glass in combination with other oxides such as MgO and Al_2O_3. However, when too much of TiO_2 is introduced, glass tends to show phase separation and hence disadvantageously degrade crystallization stability and homogeneity of glass. Therefore, the content: of TiO_2 is suitably 25% or less, preferably 20% or less, To obtain distinct effects of the addition of TiO_2, the content of TiO_2 is preferably 1% or more.

[0052] CaO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics at a high temperature like MgO. CaO, like MgO, also contributes to improvement of crystallization stability of glass and homogeneity of glass. As described above, when the content of Al_2O_3 is less than 20%, it is preferred to introduce a large amount of MgO to maintain high specific elastic modulus of glass. In such a case, CaO is a component introduced mainly for improving melt characteristics at a high temperature and crystallization stability of glass. However, glass having crystallization stability suitable for large scale production cannot be obtained with a content of CaO exceeding 30%. Therefore, the content of CaO is suitably 30% or less, preferably 27% or less. In order to obtain distinct effects of the addition of CaO, the content of CaO is preferably 2% or more.

[0053] ZrO_2 is a component introduced mainly for enhancing durability and stiffness of glass. Addition of ZrO_2 in a small amount improves heat resistance of glass and also enhances crystallization stability against devitrification. However, the content of ZrO_2 exceeds 8%, melt characteristics of glass at a high temperature is remarkably degraded, and surface smoothness of glass deteriorates and specific gravity increases. Therefore, the content of ZrO_2 is suitably 8% or less, preferably 6% or less. In order to obtain distinct effects of the addition of ZrO_2, the content of ZrO_2 is preferably 0.5% or more.

[0054] $Y_2O_3 + TiO_2 + ZrO_2 + CaO$ is suitably in the range or 1-30%. These components are for contributing to enhancement of Young's modulus of glass and enhancement of crystallization stability. When the total amount of these components is less than 1%, Young's modulus of glass tends to be lowered and crystallization stability of glass tends to be degraded. On the other hand, these components increase specific gravity of glass, and hence introduction in a large amount may lower the specific elastic modulus of glass. Therefore, the total content of $Y_2O_3 + TiO_2 - ZrO_2 + CaO$ is suitably in the range of 1-30%, preferably in the range of 5.5-27%.

[0055] P_2O_5 and B_2O_3 are components added for controlling melt characteristics of glass at a high temperature. For example, introduction of P_2O_5 and B_2O_3 in a small amount does not substantially affect on specific elastic modulus of class but significantly lower high temperature viscosity of glass. Therefore, it is very effective for facilitating melting of glass. For improvement of melt characteristics of glass and control of crystallization stability and physical characteristics of glass, the total amount of $B_2O_3 + P_2O_5$ is suitably 5% or less, preferably 3.5% or less. In order to obtain distinct effects of the addition of B_2O_3 and P_2O_5, the total content is preferably 0.5% or more.

[0056] As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if too much of the degassing agents is added, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

[0057] The other components such as V_2O_5, Cr_2O_3, ZnO, SrO, NiO, CoO, [illegible], CuO etc. may be added for controlling melt characteristics at a high temperature, physical properties and the [illegible] of glass. For example, by adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiating with a heat lamp can be effectively performed. For improving melt characteristics of glass and controlling crystallization stability and physical properties of glass, the total amount of ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5+ V_2O_5 is suitably 5% or less, preferably 4% or less.

[0058] Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

[0059] The above-mentioned glass is alkali-free glass which does not substantially contain alkali substances. Therefore, when a film is formed on a substrate made of this glass, any alkali substances do not migrate into the film and hence the film is not adversely affected.

<u>Glass (3)</u>

[0060] Glass (3) is a composition constituted mainly for obtaining a high specific elastic modulus, and the glasses have a specific elastic modulus G of 36 × 10^6 Nm/kg or more. Glass having specific elastic modulus G of 36 × 10^6 Nm/kg or more can afford a substrate exhibiting reduced deflection. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it may exhibit a maximum deflection of 1.4 μ m or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be stably performed. To obtain a substrate exhibiting a maximum deflection of 1.25 μm or less, glass having a specific elastic modulus G of 37 × 10^6 Nm/kg or more is preferred. Glass having a specific elastic modulus of 42 × 10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflection of 1.4 μm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value-thereof is about 45 × 10^6 Nm/kg or less.

[0061] Glass (3) can have a surface roughness (Ra) of 0.9 nm (9Å) or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 0.9 nm (9Å) or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 0.5 nm (5Å) or less is preferred.

[0062] Glass (3) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflection, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

[0063] SiO_2 acts as an oxide for forming the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, glass containing more than 50% of SiO_2 cannot contain a large amount of Al_2O_3 which is a component contributing to improvement of impact resistance and mechanical strength of glass. Therefore, in order to obtain glass having a high specific elastic modulus, the upper limit of the SiO_2 content is suitably 50%. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is suitably 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-50%, preferably in the range of 30-49%.

[0064] Al_2O_3 is very important as a component for imparting high heat resistance and high durability to glass and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, when MgO is used with a content of 25% or less in order to further enhance flexural strength and impact resistance, a content of Al_2O_3 less than 10% cannot sufficiently improve Young's modulus of glass and hence a desired specific elastic modulus cannot be obtained. When the content of Al_2O_3 exceeds 37%, melt characteristics of glass at a high temperature is degraded, and hence homogenous glass cannot obtained and crystallization stability of glass is degraded. Therefore, the upper limit of the content of Al_2O_3 is suitably 37%. The content of Al_2O_3 is suitably in the range of 10-37%, preferably in the range of 11-35%.

[0065] MgO is a component introduced for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of

glass. In particular, whe[redacted]$_3$, which is a component for greatly improving [redacted]'s modulus of glass, is introduced in a large amount, MgO i[redacted]ferably used for improving stability of glass struc[redacted]as well as lowering melt characteristics at a high temperature to facilitate melting of glass. However, sufficiently stable glass suitable for large scale production containing a large amount of Al_2O_3 for enhancing impact resistance and strength of glass cannot be obtained with a MgO content exceeding 40%. On the other hand, with a content of MgO of less than 5%, glass exhibiting sufficient stability and high specific elastic modulus cannot be obtained. Therefore, the content of MgO is suitably in the range of 5-40%, preferably in the range of 7-35%.

[0066] TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves melt characteristics of glass and enhances structure stability and durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. In particular, in glass containing a large amount of Al_2O_3, TiO_2 improves melt characteristics at a high temperature and crystallization stability of the glass and is surely expected to enhance specific elastic modulus of the glass in combination with Al_2O_3. However, when the content of TiO_2 exceeds 25%, glass tends to show phase separation and hence crystallization stability and homogeneity of glass tend to be disadvantageously degraded. On the other hand, addition of TiO_2 of 1% or more markedly improves melt characteristics of glass at a high temperature. Therefore, the content of TiO_2 is suitably in the range of 1-25%, preferably in the range of 2-20%.

[0067] Y_2O_3 is a component introduced for improving Young's modulus, enhancing crystallization stability of glass and improving durability and melt characteristics at a high temperature of glass. In particular, when a large amount of Al_2O_3 is introduced for enhancing flexural strength, impact resistance and the like, Y_2O_3 exerts excellent effect as a melting aid for Al_2O_3. For example, when Al_2O_3 of 25% or more is introduced into glass, homogenous glass can be obtained by adding Y_2O_3. However, since Y_2O_3 is relatively expensive, a smaller content is preferred from economical point of view. In addition, while a proper amount of Y_2O_3 greatly contributes to enhancement of specific elastic modulus of glass, when the content of Y_2O_3 exceeds 17%, increase of specific gravity overwhelms increase of Young's modulus of glass, and hence the addition can no longer contribute to improvement of specific elastic modulus of the glass. Therefore, the content of Y_2O_3 is suitably in the range of 0-17%, preferably in the range of 1-15% depending on the introduced amount of Al_2O_3.

[0068] CaO is a component capable of enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature like MgO. CaO also contributes to improvement of crystallization stability of glass and homogeneity of glass. When a large amount of Al_2O_3 is introduced as a component greatly contributing to improvement of Young's modulus of glass, it is preferred to introduce CaO to improve stability of glass structure and to lower high temperature viscosity to facilitate melting. When the content of CaO exceeds 25%, glass containing a large amount of Al_2O_3 for enhancing impact resistance and strength of glass and having crystallization stability suitable for large scale production cannot be obtained. Therefore, the upper limit of the content of CaO is suitably 25%. In order to obtain distinct effects of the addition of CaO, the content of CaO is preferably 2% or more.

[0069] ZrO_2 is a component introduced mainly for enhancing durability and stiffness of glass. Addition of a small amount of ZrO_2 improves heat resistance of glass and also enhances crystallization stability against devitrification. However, when the content of ZrO_2 exceeds 8%, melt characteristics of glass at a high temperature is markedly degraded, and surface smoothness of glass deteriorates and specific gravity increases. Therefore, the content of ZrO_2 is suitably 8% or less, preferably 6% or less. In order to obtain distinct effects of the addition of ZrO_2, the content of ZrO_2 is preferably 0.5% or more.

[0070] As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if the amount of the degassing agents is too much, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible used for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

[0071] The other components such as P_2O_5, V_2O_5, B_2O_3, Cr_2O_3, ZnO, SrO, NiO, CoO, Fe_2O_3, CuO etc. may be added for controlling melt characteristics at a high temperature and physical properties and the like of glass. For example, addition of a small amount of P_2O_5 does not substantially affect specific elastic modulus of glass but significantly lower high temperature viscosity of glass, and hence it is effective for facilitating melting of glass. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed. For improving melt characteristics of glass at a high temperature and controlling physical and thermal properties of glass, the total amount of ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5+ V_2O_5 is suitably 5% or less.

[0072] Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

[0073] When Li_2O is contained in the glass, chemical tempering treatment by ion exchange can be performed to

enhance strength of the[illegible]. On the other hand, when the glass is alkali-fr[illegible]ass not containing Li_2O, any alkali substances do not migr[illegible]o a film formed on a substrate and hence the fil[illegible]not adversely affected.

Glass (4)

[0074] Glass (4) is a composition constituted mainly for obtaining a high specific elastic modulus, and the glasses have a specific elastic modulus G of 36×10^6 Nm/kg or more. Glass having specific elastic modulus G of 36×10^6 Nm/kg or more can afford a substrate exhibiting reduced deflection. For example, even when it is made into a substrate having a thickness of 0.43 mm or less required for magnetic recording media discs of the next generation, it exhibits a maximum deflection of 1.4 µm or less. As a result, excellent flying stability of magnetic heads can be obtained and hence reconstruction of recorded information can be stably performed. To obtain a substrate exhibiting a maximum deflection of 1.25 µm or less, glass having a specific elastic modulus G of 37×10^6 Nm/kg or more is preferred. Glass having a specific elastic modulus of 42×10^6 Nm/kg or more is more preferred because such glass can afford a substrate which exhibits a maximum deflection of 1.4 µm or less even if it is made into a substrate of a thickness of 0.38 mm or less to meet the demand of further thinner magnetic discs. While a specific elastic modulus as high as possible is preferred, practical value thereof is about 45×10^6 Nm/kg or less.

[0075] Glass (4) can have a surface roughness (Ra) of 0.9 nm (9Å) or less. Higher surface smoothness enables a smaller flying height of magnetic heads, which is required for higher density of magnetic discs. A surface roughness (Ra) of 0.9 nm (9Å) or less can realize a flying height smaller than the conventional flying height. For realizing further higher density of magnetic discs, a surface roughness (Ra) of 0.5 nm (5Å) or less is preferred.

[0076] Glass (4) is glass having a transition temperature of 700°C or higher. Because of a transition temperature of 700°C or higher, a substrate having heat resistance higher than that of the conventional one, in addition to the reduced deflection, can be obtained. Thus, a magnetic disc having improved magnetic characteristics such as coercive force can be provided.

[0077] SiO_2 acts as an oxide for forming the network structure of glass and is a component for improving stability of glass structure, i.e., enhancing crystallization stability against devitrification. Further, SiO_2 in combination with an intermediate oxide such as Al_2O_3 can enhance mechanical properties of glass necessary for substrates for magnetic recording media such as strength and stiffness and also improve heat resistance of glass. However, oxide glass of CaO-Al_2O_3-SiO_2 system containing more than 50% of SiO_2 no longer exhibits a specific elastic modulus exceeding 36×10^6 Nm/kg, and therefore the content of SiO_2 is suitably 50% or less. On the other hand, a SiO_2 content less than 25% significantly degrades the crystallization stability of glass and sufficiently stable glass suitable for large scale production cannot be obtained with such a content. Therefore, the lower limit of the SiO_2 content is 25%. Accordingly, the content of SiO_2 is suitably in the range of 25-50%, preferably in the range of 30-50%.

[0078] Al_2O_3 is very important as a component for imparting high heat resistance and high durability and also as a component for enhancing stability of glass structure and stiffness together with SiO_2. In particular, when Al_2O_3 is introduced into glass to substitute SiO_2, Al_2O_3 enters into the skeletal structure of glass and markedly enhance Young's modulus and heat resistance of glass as a skeletal structure-forming component. That is, Al_2O_3 is a component essential for enhancing Young's modulus and improving heat resistance. However, a content of Al_2O_3 less than 20% cannot sufficiently improve Young's modulus of glass. On the other hand, when the content of Al_2O_3 exceeds 40%, melt characteristics of glass at a high temperature is degraded and hence homogenous glass cannot obtained, and crystallization stability of glass is also degraded. Therefore, the content of Al_2O_3 is suitably in the range of 20-40%, preferably in the range of 21-37%.

[0079] CaO is a component for enhancing stiffness and strength of glass and improving melt characteristics at a high temperature. It also contributes to improvement of crystallization stability of glass and homogeneity of glass. In particular, when a large amount of Al_2O_3 is introduced as a component greatly contributing to improvement of Young's modulus of glass, it is necessary to introduce CaO to improve stability of glass structure and to lower high temperature viscosity to facilitate melting of glass. However, when the content of CaO is less than 8%, crystallization stability of glass is markedly degraded. On the other hand, when the content of CaO exceeds 30%, Young' s modulus of glass tends to be lowered. Therefore, the content of CaO is suitably in the range of 8-30%, preferably in the range of 10-27%.

[0080] Y_2O_3 is a component introduced for improving Young's modulus, enhancing crystallization stability of glass and improving durability and melt characteristics of glass at a high temperature. In particular, when a large amount of Al_2O_3 is introduced for enhancing Young's modulus of glass, Y_2O_3 exerts excellent effect as a melting aid for Al_2O_3. For example, when Al_2O_3 of 25% or more is introduced into glass, homogenous glass can be obtained by adding Y_2O_3 as a melting aid. However, since Y_2O_3 is relatively expensive, its content is preferably a relatively small amount, i.e., 15% or less depending on the properties required for glass. On the other hand, the content of Y_2O_3 is too small, melt characteristics of glass at a high temperature is degraded and specific elastic modulus of glass is lowered. Therefore, the lower limit of the content of Y_2O_3 is suitably 2%. Accordingly, the content of Y_2O_3 is suitably in the range of 2-15%, preferably in the range of 3-12%.

[0081] MgO is a component for enhancing stiffness and strength of glass and improving melt characteristics of glass at a high temperature. It also contributes to improvement of crystallization stability and homogeneity of glass, and improves specific elastic modulus. This component may optionally be added as desired. However, when the content of MgO exceeds 20%, the essential component, CaO, cannot be introduced in a large amount and thus crystallization stability tends to be lowered. Therefore, the upper limit of the content of MgO is suitably 20%. In order to obtain distinct effects of addition of MgO, its content is preferably 5% or more.

[0082] TiO_2 acts as both of a glass skeletal structure-forming component and a modifying component. It lowers high temperature viscosity, improves solubility of glass and enhances structure stability and durability. By introducing TiO_2 as a glass component, Young's modulus of glass can be markedly improved without significantly increasing specific gravity of glass. However, if too much amount of TiO_2 is introduced into CaO-Al_2O_3-SiO_2 system oxide glass, the glass tends to show phase separation and crystallization stability and homogeneity are disadvantageously degraded. Therefore, the content of TiO_2 is suitably 25% or less, preferably 20% or less. In order to obtain distinct effects of addition of TiO_2, its content is preferably 1% or more.

[0083] Li_2O is a component mainly for lowering high temperature viscosity of glass to facilitate melting. In particular, when the Al_2O_3 content is high, addition of small amount of Li_2O is very effective for obtaining homogenous glass. However, if its content is too high, durability of glass is degraded and Young's modulus tends to be lowered. Therefore, the content of Li_2O is suitably 15% or less, preferably 12% or less. In order to obtain distinct effects of the addition of Li_2O, the content of Li_2O is preferably 1.5% or more.

[0084] As_2O_3 and Sb_2O_3 are components added as degassing agents in order to obtain homogenous glass. By adding As_2O_3 or Sb_2O_3 or both in a suitable amount selected depending on high temperature viscosity of glass, more homogenous glass can be obtained. However, if the amount of the degassing agents is too much, specific gravity of glass is increased and specific elastic modulus tends to be lowered. In addition, they may react with and damage a platinum crucible for melting. Therefore, the content is suitably 3% or less, preferably 2% or less. In order to obtain distinct effects of the addition of the degassing agent, the content is preferably 0.2% or more.

[0085] The other components such as P_2O_5, V_2O_5, B_2O_3, Cr_2O_3, ZnO, SrO, NiO, CoO, Fe_2O_3, CuO etc. may be added for controlling melt characteristics at a high temperature and physical properties and the like of glass. For example, addition of a small amount of P_2O_5 does not substantially affect specific elastic modulus of glass but significantly lower high temperature viscosity of glass and therefore melting of glass is facilitated. By adding a small amount of a colorant such as V_2O_5, Cr_2O_3, CuO and CoO to glass, infrared ray absorbing property can be imparted to the glass and heating treatment of magnetic layer by irradiation with a heat lamp can be effectively performed. For controlling physical and thermal properties of glass, the total amount of $ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5$ is suitably 5% or less.

[0086] Other than the components mentioned above, addition of Fe_2O_3 and the like which are sometimes contained as impurities of starting material and a clarifier for glass such as Cl, F and SO_3 in an amount of 1% or less does not substantially degrade the intended physical characteristics of the glass according to the present invention.

Substrate for information recording media

[0087] Substrates for information recording media of the present invention characterized by being composed of one of the glasses (1)-(4) mentioned above. Examples of information recording media includes magnetic recording media, and examples of magnetic recording media includes magnetic discs such as hard discs. Size and shape of the substrate can be selected in view of its use. The substrate of the present invention is characterized by exhibiting high surface smoothness. High surface smoothness means 0.9 nm (9 Å) or less, preferably 0.5 nm (5Å) or less of surface roughness (Ra). Since distance between magnetic head and magnetic disc can be reduced by a magnetic disc using a substrate with high surface smoothness, higher recording density is obtainable.

Production method

[0088] The glass and the glass substrate of the present invention is not particularly limited, and can be produced by a conventional production method. For example, glass materials of a given composition can be melted by the high temperature melting method, i.e., melted in air or inert gas atmosphere, homogenized by bubbling, addition of degassing agent, stirring or the like and molded into plate glass by well-known press method, down draw method or the like. Then, substrates for magnetic recording media of a desired size and shape can be obtained from the plate glass by processing such as cutting and polishing. In the polishing, surface roughness (Ra) 0.9 nm of (9Å) preferably 0.3-0.5 nm (3-5Å) can be obtained by wrapping or polishing with polishing powder of cerium oxide or the like.

[0089] Because the glass of the present invention is excellent in the heat-resistance, surface smoothness, chemical resistance, optical properties and mechanical strength, it can be suitably used for substrates of information recording media such as magnetic discs, glass substrates for magnet optical discs, glass substrates for optoelectronics such as

those for optical discs, heat-resistant substrates for low temperature polycrystalline silicon liquid crystal display devices, which are expected as next generation LCD, substrates for various electric and electronic components or the like.

Magnetic disc

[0090] A magnetic disc (hard disk) comprising a substrate composed of the glass of the present invention described above and at least a magnetic layer formed on a main surface of the substrate will be explained hereinafter.

[0091] As layers other than the magnetic layer, underlying layer, protective layer, lubricating layer, unevenness control layer and the like are optionally formed depending on functions of the disc. These layers can be formed by various thin film-forming techniques.

[0092] Material for the magnetic layer is not particularly limited. For example, in addition to Co magnetic layers, ferrite magnetic layers, iron-rare earth metal magnetic layers and the like can be mentioned. The magnetic layer may be either for horizontal magnetic recording or vertical magnetic recording.

[0093] Specific examples of the magnetic layer include, for example, those containing Co as a main component such as CoPt, CoCr, CoNi, CoNiCr, CoCrTa, CoPtCr and CoNiCrPt, CoNiCrTa, CoCrPtTa, CoCrPtSiO and the like. The magnetic layer may be consisted of multiple layers comprising a non-magnetic layer for noise reduction separating magnetic layers.

[0094] The underlying layer of the magnetic layer may be selected depending on the nature of the magnetic layer. For example, the underlying layer may be those comprising one or more of non-magnetic metals such as Cr, Mo, Ta, Ti, W, V, B and Al, oxides, nitride, carbides and the like of those metals. For a magnetic layer comprising Co as the main component, an underlying layer of pure Cr or Cr alloy is preferred for improving magnetic characteristics. The underlying layer is not limited to a monolayer, and may be composed of identical or nonidentical multiple layers. For example, the underlying layer may be a multi-layer underlying layer such as Al/Cr/CrMo and Al/Cr/Cr.

[0095] The unevenness control layer for preventing absorption of magnetic disc to magnetic head may be provided between the substrate and the magnetic layer or on the magnetic layer. Because surface roughness of the disc is properly controlled by the unevenness control layer, the magnetic disc is prevented from being absorbed to the magnetic disc and hence a highly reliable magnetic disc can be provided. Various materials and production methods for the unevenness control layer have been known and they are not particularly limited. For example, the material of the unevenness control layer may be one or more metals selected from Al, Ag, Ti, Nb, Ta, Bi, Si, Zr, Cr, Cu, Au, Sn, Pd, Sb, Ge, Mg and the like, alloys thereof, oxides, nitrides, carbides thereof and the like. For the ease of production, those produced from metals containing Al as a main component such as pure Al, Al alloys, Al oxides and Al nitrides are preferred.

[0096] For good head stiction, surface roughness of the unevenness forming layer is preferably Rmax of 5-30 nm (50-300Å), more preferably Rmax of 10-20 nm (100-200Å). When the Rmax is less than 5 nm (50 Å), the disc surface is nearly flat, and hence the magnetic head and the disc are absorbed to each other. This may disadvantageously cause damage of the magnetic head and the magnetic disc, and head crash. On the other hand, when the Rmax exceeds 30 nm (300Å), glide height becomes larger and recording density is disadvantageously lowered.

[0097] Unevenness may be provided on the surface of the glass substrate by a texturing treatment such as etching treatment and irradiation of laser lights instead of providing the unevenness control layer.

[0098] The protective layer may be, for example, a Cr layer, Cr alloy layer, carbon layer, zirconia layer, silica layer or the like. These protective layers can be successively formed by an inline sputtering apparatus together with the underlying layer, the magnetic layer and the like. These protective layers may have either monolayer structure or multilayer structure comprising identical or different layers.

[0099] Another protective layer may be provided on or instead of the protective layer explained above. For example, a silicon oxide (SiO_2) layer may be formed on the protective layer mentioned above by applying tetraalkoxysilane diluted in an alcoholic solvent, in which colloidal silica is further dispersed, and sintering the applied layer. This layer functions as both a protective layer and as an unevenness control layer.

[0100] While various kinds of layers have been proposed as the lubricating layer, it is generally formed by applying a liquid lubricating agent, perfluoropolyether, diluted in a solvent such as freons by dipping, spin coating, spraying or the like and subjecting the coated layer to a heat treatment as required.

EXAMPLES

[0101] The present invention will be further explained with reference to the following examples.

[0102] The glass compositions given in Examples 1-61 which are examples of glasses (1)-(4) are shown in Tables 1-5.

[0103] As the starting materials of these glasses, SiO_2, Al_2O_3, $Al(OH)_3$, MgO, $CaCO_3$, Y_2O_3, TiO_2, ZrO_2, Li_2CO_3 and the like were weighed into 250-300 g portions according to the given compositions shown in Tables 1-5 and mixed sufficiently to provide formulated batches. Each of them was charged in a platinum crucible and melted in air for 3 to

5 hours at 1550°C. After melting, the glass melt was cast into a carbon mold having a size of 180 × 15 × 25 mm or ϕ 67 × 5 mm, left to cool to the glass transition temperature, immediately transferred into an annealing furnace, annealed in the glass transition temperature range for about 1 hour and left to cool to room temperature in the furnace. The resulting glasses did not contain crystals deposited which can be observed by a microscope.

[0104] Glass pieces having a size of 180 × 15 × 25 mm were polished into pieces having a size of 100 × 10 × 10 mm or 10 × 10 × 20 mm and used as samples for measurements of Young's modulus, specific gravity and DSC. Glass discs of ϕ67 x thickness of 5 mm were polished into discs of ϕ65 x thickness of 0.5 mm and used as samples for measurement of surface roughness. The plate glass pieces of 10 × 1 × 20 mm were ground into 150 mesh powder, and 50 mg of the resulting powder were charged into a platinum pan and subjected to the DSC measurement using MAC-3300 DSC apparatus. The measurement of Young's modulus was achieved by the ultrasonic method using samples of 100 × 10 × 10 mm.

[0105] Values of surface roughness, specific gravity, Young's modulus, specific elastic modulus and transition temperature obtained in the measurements for the glasses of Examples 1-61 are shown in Tables 1-5 together with the glass compositions.

[0106] The obtained glasses were cut into discs and their main surfaces were polished with cerium oxide to afford magnetic disc substrates having a radius of outer circular periphery of 32.5 mm, radius of inner circular periphery of 10.0 mm and thickness of 0.43 mm. The results of deflection measurement of the obtained discs are also shown in Tables 1-5.

[0107] For comparison, compositions and characteristics of the ion exchanged glass substrate described in Japanese Patent Unexamined Publication No. Hei 1-239036 and the glass substrate described in Japanese Patent Unexamined Publication No. Hei 7-187711 are shown in Table 5 as Comparative Examples 1 and 2.

Table 1

(molar %)

Example	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	49.00	45.00	44.00	45.00	40.00	45.00	45.00	34.00	30.00	35.00	35.00	35.00	40.00
Al_2O_3	21.00	20.00	17.00	12.50	12.50	10.00	7.50	17.00	15.00	15.00	17.00	15.00	20.00
MgO	25.00	25.00	21.00	30.00	30.00	30.00	30.00	15.00	15.00	15.00	20.00	20.00	30.00
CaO	5.00	10.00	14.00	5.00	5.00	5.00	5.00	20.00	20.00	15.00	13.00	10.00	—
Y_2O_3	—	—	—	7.50	7.50	5.00	7.50	—	—	—	—	5.00	5.00
TiO_2	—	—	4.00	—	5.00	5.00	—	14.00	20.00	20.00	15.00	15.00	5.00
ZrO_2	—	—	—	—	—	—	5.00	—	—	—	—	—	—
Li_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	3	4	4	4	4	4	5	4	5	5	4	4	4
Specific gravity (g/cc)	2.72	2.72	2.82	3.17	3.26	3.11	3.43	2.97	3.11	3.04	2.97	3.23	3.10
Young's modulus (GPa)	108.8	107.4	108.4	119.9	125.1	118.9	126.8	113.5	119.5	120.0	116.5	123.9	124.5
Specific elastic modulus(10^6Nm/kg)	40	39.5	38.4	37.8	38.4	38.2	37.00	38.2	38.4	39.5	39.2	38.3	40 2
Transition temperature(℃)	778	769	738	757	752	750	764	722	709	725	717	737	760
h-0.43 Deflexion (μm)	1.18	1.19	1.22	1.23	1.20	1.22	1.26	1.22	1.21	1.19	1.20	1.21	1 16

Table 2

(molar %)

Example	14	15	16	17	18	19	20	21	22	23	24	25	26
SiO_2	40.00	35.00	40.00	45.00	50.00	35.00	40.00	40.00	40.00	40.00	35.00	40.00	45.00
Al_2O_3	25.00	15.00	15.00	15.00	15.00	25.00	15.00	20.00	20.00	20.00	33.00	30.00	25.00
MgO	15.00	15.00	15.00	15.00	15.00	15.00	25.00	25.00	20.00	15.00	7.00	7.00	15.00
CaO	10.00	20.00	20.00	—	20.00	20.00	10.00	5.00	10.00	15.00	18.00	13.00	10.00
Y_2O_3	5.00	—	—	—	—	5.00	5.00	5.00	5.00	5.00	5.00	5.00	—
TiO_2	5.00	15.00	10.00	5.00	—	10.00	5.00	5.00	5.00	5.00	2.00	5.00	5.00
ZrO_2	—	—	—	—	—	—	—	—	—	—	—	—	—
Li_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	4	5	4	4	4	5	4	4	4	4	4	5	4
Specific gravity (g/cc)	3.06	2.99	2.91	2.83	2.75	3.15	3.14	3.10	3.11	3.12	3.045	3.04	2.78
Young's modulus (GPa)	118.3	113.4	109.2	105.1	101.9	122.5	119.4	121.7	119.0	117.0	116.4	116.1	109.7
Specific elastic modulus (10^6Nm/kg)	38.6	37.9	37.5	37.1	37.1	38.9	38.1	39.3	38.3	37.5	38.2	38.2	39.5
Transition temperature (℃)	767	724	730	742	753	761	751	757	763	787	803	795	775
h=0.43 Deflexion (μm)	1.21	1.23	1.25	1.27	1.27	1.20	1.22	1.18	1.22	1.24	1.22	1.23	1.19

Table 3

(molar %)

Example	27	28	29	30	31	32	33	34	35	36	37	38	39
SiO_2	45.00	45.00	42.00	43.00	45.00	41.00	40.00	40.00	35.00	40.00	37.00	36.00	36.50
Al_2O_3	25.00	25.00	28.00	25.00	25.00	27.00	27.00	32.00	33.00	32.00	35.00	35.00	33.00
MgO	12.00	10.00	8.00	15.00	22.00	20.00	17.00	17.00	—	—	—	—	—
CaO	10.00	10.00	15.00	10.00	—	—	—	—	25.00	20.00	16.00	19.00	22.00
Y_2O_3	—	—	3.50	—	1.00	4.00	8.00	8.00	5.00	8.00	5.00	5.00	4.00
TiO_2	8.00	5.00	3.50	5.00	7.00	8.00	8.00	3.00	2.00	—	—	—	2.00
ZrO_2	—	—	—	2.00	—	—	—	—	—	—	—	—	—
Li_2O	—	5.00	—	—	—	—	—	—	—	—	7.00	5.00	2.50
Surface roughness Ra (Å)	5	4	3	4	3	4	4	4	4	4	5	4	4
Specific gravity (g/cc)	2.795	2.724	2.952	2.841	2.836	3.024	3.218	3.167	3.028	3.114	2.933	2.963	2.952
Young's modulus (GPa)	109.7	107.4	118.5	112.0	116.0	123.1	127.3	127.4	112.4	116.0	113.0	112.4	112.1
Specific elastic modulus (10^6Nm/kg)	39.2	39.4	40.1	39.5	40.8	40.8	39.5	40.2	37.1	37.2	38.6	38.3	38.0
Transition temperature (℃)	760	700	786	767	769	778	778	802	828	844	742	758	771
h=0.43 Deflexion (μm)	1.20	1.20	1.17	1.19	1.15	1.15	1.18	1.16	1.26	1.25	1.22	1.23	1.24

Table 4

(molar %)

Example	40	41	42	43	44	45	46	47	48	49	50	51	52
SiO_2	38.00	35.00	43.00	41.00	40.00	40.00	44.00	40.00	40.00	44.00	44.00	44.00	40.00
Al_2O_3	32.00	37.00	30.00	30.00	25.00	30.00	25.00	15.00	12.50	20.00	15.00	10.00	15.00
MgO	—	—	17.00	18.00	25.00	20.00	25.00	30.00	30.00	30.00	35.00	40.00	35.00
CaO	15.00	10.00	—	—	—	—	—	—	—	—	—	—	—
Y_2O_3	5.00	8.00	6.00	7.00	5.00	5.00	1.00	10.00	12.50	1.00	1.00	1.00	5.00
TiO_2	—	—	4.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
ZrO_2	—	—	—	—	—	—	—	—	—	—	—	—	—
Li_2O	10.00	10.00	—	—	—	—	—	—	—	—	—	—	—
Surface roughness Ra (Å)	4	5	4	4	4	4	4	4	4	3	3	4	3
Specific gravity (g/cc)	2.905	3.022	3.071	3.14	3.063	3.057	2.833	3.386	3.515	2.85	2.87	2.89	3.119
Young's modulus (GPa)	111.4	115.5	124.3	128.9	124.1	124.2	117	129.8	131.9	116.3	116.0	116.1	123.8
Specific elastic modulus (10^6Nm/kg)	38.3	38.2	40.5	41.1	40.5	40.6	41.3	38.3	37.5	40.8	40.6	40.2	39.7
Transition temperature (℃)	710	727	791	799	778	785	768	773	778	758	743	736	751
h=0.43 Deflexion (μm)	1.23	1.23	1.16	1.14	1.15	1.15	1.14	1.22	1.24	1.15	1.15	1.17	1.18

Table 5

(molar %)

Example	53	54	55	56	57	58	59	60	61	Comparative 1	Comparative 2
SiO_2	40.00	40.00	40.00	40.00	35.00	43.00	40.00	40.00	45.00	SiO_2: 73.0	SiO_2: 52.0
Al_2O_3	10.00	10.00	7.50	15.00	15.00	21.00	25.00	17.00	25.50	Al_2O_3: 0.6	Al_2O_3: 1.0
MgO	40.00	35.00	40.00	25.00	35.00	30.00	25.00	35.00	23.00	CaO: 7.0	CaO: 16.0
CaO	—	—	—	—	—	—	—	—	—	Na_2O: 9.0	Na_2O: 7.0
Y_2O_3	5.00	10.00	7.50	15.00	5.00	1.00	5.00	3.00	3.00	K_2O: 9.0	K_2O: 5.0
TiO_2	5.00	5.00	5.00	5.00	10.00	—	—	—	2.00	ZnO: 2.0	F:19.0
ZrO_2	—	—	—	—	—	5.00	5.00	5.00	2.00	As_2O_3: 0.2	-
Li_2O	—	—	—	—	—	—	—	—	—	—	-
Surface roughness Ra (Å)	4	3	4	4	5	4	5	4	4	12	25
Specific gravity (g/cc)	3.166	3.411	3.35	3.604	3.225	2.952	3.152	3.110	2.97	2.60	2.60
Young's modulus (GPa)	125.6	129.6	128.5	134.0	129.5	120.0	126.4	124.7	126.5	79.0	91.0
Specific elastic modulus (10^6Nm/kg)	39.7	38.0	38.4	37.2	40.2	40.7	40.1	40.1	42.6	30.3	35.0
Transition temperature(℃)	752	765	755	790	746	771	779	763	791	554	-
h=0.43 Deflexion (μm)	1.18	1.22	1.21	1.25	1.16	1.15	1.17	1.16	1.09	—	-

[0108] As seen from the results shown in Tables 1-5, the glasses of Examples 1-61 have a high glass transition temperature and hence have sufficiently high heat resistance enough to bear desired heat treatment (usually at a temperature of 700°C or lower) . In particular, they exhibits high glass strength characteristics such as Young's modulus and/or specific elastic modulus. Therefore, when they are used as substrates for magnetic recording media, they are not likely to exhibit warp or walking even when they are rotated at a high speed, and hence they can meet the demand of further thinner substrates. In addition, they can have so excellent flatness as to be polished to a surface roughness (Ra) of 0.5 nm (5Å) or less, and therefore they can realize smaller flying height. Furthermore, the glasses of Examples 1-61 also exhibit reduced deflection. Therefore, the glasses of the present invention are useful as glass substrates for magnetic recording media.

[0109] On the other hand, while the chemically tempered glass substrate of Comparative Example 1 is excellent in surface smoothness and flatness, it is substantially inferior to the glass substrates of the present invention in heat resistance and strength characteristics such as specific elastic modulus. Therefore, when it is used for producing magnetic recording media, it cannot be subjected to sufficient heat treatment for the magnetic layer to obtain high coercive force and hence magnetic recording media having high coercive force cannot be provided. Moreover, such a glass having a low specific elastic modulus of around 30×10^6 Nm/kg suffers severe warp and deflection when it is made into substrates and therefore it cannot be used for thinner substrates.

[0110] The crystallized glass substrate of Comparative Example 2 is significantly inferior to the glasses of the present invention as to specific elastic modulus and surface smoothness. In particular, the surface smoothness of the substrate is degraded by relatively large crystal particles and hence higher recording density cannot be achieved.

[0111] The glasses of the present invention have high Young's modulus, high specific elastic modulus and high heat resistance, and therefore they are extremely useful as substrates for magnetic discs.

Method for producing hard disc

[0112] As shown in Fig. 1, a magnetic disc 1 comprises a glass substrate 2 made of the glass of the above Example 1, on which unevenness control layer 3, underlying layer 4, magnetic layer 5, protective layer 6 and lubricating layer 7 are provided in this order.

[0113] Each layer will be explained in detail. The substrate 1 was a disc having an outer circular periphery radius of 32.5 mm, inner circular periphery radius of 10.0 mm and thickness of 0.43 mm, whose main surfaces were subjected to precision polishing so that they should have surface roughness Ra of 0.4 nm (4 Å) and Rmax of 4 nm (40Å)

[0114] The unevenness control layer is a thin AlN layer of 5-35% nitrogen content having average roughness of 5 nm (50Å) and surface roughness Rmax of 15 nm (150 Å.)

[0115] The underlying layer is a thin layer of CrV composed of Cr: 83 at% and V: 17 at% having a thickness of about 60 nm (600Å.)

[0116] The magnetic layer is a thin layer of CoPtCr composed of Co: 76 at%, Pt: 6.6 at%, Cr: 17.4 at% having a thickness of about 30 nm (300Å.)

[0117] The protective layer is a carbon thin layer having a thickness of about 10 nm (100Å.)

[0118] The lubricating layer is a layer having a thickness of 0.8 nm (8Å), which was formed by applying perfluoropolyether on the carbon protective layer by spin coating.

[0119] The method for producing magnetic discs will be explained hereinafter.

[0120] The glass of Example 1 was cut into a disc having an outer circular periphery radius of 32.5 mm, inner circular periphery radius of 10.0 mm and thickness of 0.5 mm and the both main surfaces were subjected to precision polishing so that they should have surface roughness Ra of 0.4 nm (4Å) and Rmax of 4 nm (40Å) to afford a glass substrate for magnetic discs.

[0121] Subsequently, the above glass substrate was placed on a substrate holder and transferred into a charging chamber of inline sputtering apparatus. Then, the holder on which the glass substrate was placed was transferred to a first chamber where an Al target was etched and sputtering was performed at a pressure of 4 mtorr and substrate temperature of 350°C in an atmosphere of Ar + N_2 gas (N_2 = 4%). As a result, an AlN thin layer having surface roughness Rmax of 150Å and thickness of 50Å (unevenness forming layer) was provided on the glass substrate.

[0122] The holder on which the glass substrate having the formed AlN layer was placed was then serially transferred into a second chamber provided with a CrV target (Cr: 83 at%, V: 17 at%) and a third chamber provided with a CoPtCr target (Co: 76 at%, Pt: 6.6 at%, Cr: 17.4 at%) successively, and thin layers were formed on the substrate. Sputtering was performed at a pressure of 2 mtorr and substrate temperature of 350°C in an Ar atmosphere, thereby a CrV underlying layer having a thickness of about 600 Å and CoPtCr magnetic layer having a thickness of about 300 Å were formed.

[0123] The substrate having the formed unevenness control layer, underlying layer and magnetic layer was then transferred to a fourth chamber provided with a heater for heat treatment. The fourth chamber had an inner atmosphere of Ar gas ((pressure: 2 mtorr) and the heat treatment was performed.

[0124] The substrate w[illegible]n transferred into a fifth chamber provided with [illegible]bon target, and a carbon protective layer having a thickness o[illegible]out 100Å was formed under the same condition as [illegible]ed for forming of the CrV underlying layer and the CoPtCr magnetic layer except that the layer was formed in an atmosphere of Ar + H_2 gas (H_2 = 6%).

[0125] Finally, the substrate after forming the carbon protective layer was taken out from the above inline sputtering apparatus, and a lubricating layer having a thickness of 8 A was formed by applying perfluoropolyether on the carbon protective layer by dipping to produce a magnetic disc.

[0126] The present invention was explained by referring to the preferred examples, but the present invention is not limited to the above examples.

Utility in Industry

[0127] By using glass of the present invention, a glass substrate having high specific elastic modulus of 36×10^6 Nm/kg or more or high Young's modulus of 110 GPa or more, high transition temperature of 700°C or higher (high heat resistance), excellent surface smoothness (surface roughness Ra < 0.9 nm (9Å) and high strength can be provided. Because the glass of the present invention has excellent heat resistance, it can be subjected to heat treatment necessary for improving magnetic layer characteristics without causing deformation of substrates made from it. Therefore, it can have excellent flatness and hence achieve smaller flying height of magnetic head, i.e., higher recording density. Moreover, it exhibits high specific elastic modulus and high strength, it can realize thinner magnetic discs and prevent breakdown of magnetic discs. Furthermore, it can be stably obtained as glass and easily produced in an industrial scale. Therefore, it can be surely expected to be used as economical glass for substrates of next generation magnetic recording media.

Claims

1. Glass for substrates having a specific elastic modulus G of 36×10^6 Nm/kg or more.

2. The glass of claim 1 whose surface roughness (Ra) can be made 0.9 nm (9 Å) or less.

3. The glass of claim 1 which has a transition temperature of 700°C or higher .

4. The glass of claim 1 having a composition, as oxides constituting the glass, of 25-52 mole-% SiO_2, 5-35 mole-% Al_2O_3, 15-45 mole-% MgO, 0-17 mole-% Y_2O_3, 0-25 mole-% TiO_2, 0-8 mole-% ZrO_2, 1-30 mole-% CaO, provided that Y_2O_3 + TiO_2 + ZrO_2 + CaO is 5-30 mole-% and B_2O_3 + P_2O_5 is 0-5 mole-%.

5. The glass of claim 4 further containing 0-3 mole-% As_2O_3+ Sb_2O_3 and 0-5 mole-% ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3+ P_2O_5+V_2O_5.

6. The glass of claim 1 having a composition, as oxides constituting the glass, of 25-50 mole-% SiO_2, 10-37 mole-% Al_2O_3, 5-40 mole-% MgO, and 1-25 mole-% TiO_2

7. The glass of claim 6 further containing 0-17 mole-% Y_2O_3, 0-8 mole-% ZrO_2, 0-25 CaO mole-%, 0-3 mole-% As_2O_3 + Sb_2O_3 and 0-5 mole-% ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5.

8. The glass of claim 1 having a composition containing, as oxides constituting the glass, of 25-50 mole-% SiO_2, 20-40 mole-% Al_2O_3, 8- 30 mole-% CaO, 2-15 mole-% Y_2O_3.

9. The glass of claim 8 further containing 0-20 mole-% MgO, 0-25 mole-% TiO_2, 0-12 mole-% Li_2O, 0-3 mole-% As_2O_3+ Sb_2O_3 and 0-5 mole-% ZnO + SrO + NiO + CoO + FeO + CuO +Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5.

10. The glass of any of claims 1-9 wherein the glass exhibits a Young's modulus of 110 GPa or more.

Patentansprüche

1. Glas für Substrate mit einem spezifischen Elastizitätsmodul G von 36×10^6 Nm/kg oder mehr.

2. Glas gemäß Anspruch 1, dessen Oberflächenrauheit (Ra) zu 0,9 nm (9 Å) oder weniger erzeugt werden kann.

3. Glas gemäß Anspru[illegible] welches eine Umwandlungstemperatur von 700[illegible]der höher aufweist.

4. Glas gemäß Anspruch 1, welches eine Zusammensetzung als das Glas bildende Oxide von 25 - 52 Mol-% SiO_2, 5 - 35 Mol-% Al_2O_3, 15 - 45 Mol-% MgO, 0 - 17 Mol-% Y_2O_3, 0 - 25 Mol-% TiO_2, 0 - 8 Mol-% ZrO_2, 1 - 30 Mol-% CaO aufweist, vorausgesetzt, dass Y_2O_3 + TiO_2 + ZrO_2 + CaO 5 - 30 Mol-% beträgt und B_2O_3 + P_2O_5 0 - 5 Mol-% beträgt.

5. Glas gemäß Anspruch 4, welches darüber hinaus 0 - 3 Mol-% As_2O_3 + Sb_2O_3 und 0 - 5 Mol-% ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5 enthält.

6. Glas gemäß Anspruch 1, welches eine Zusammensetzung als das Glas bildende Oxide von 25 - 50 Mol-% SiO_2, 10 - 37 Mol-% Al_2O_3, 5 - 40 Mol-% MgO und 1 - 25 Mol-% TiO_2 aufweist.

7. Glas gemäß Anspruch 6, welches darüber hinaus 0 - 17 Mol-% Y_2O_3, 0 - 8 Mol-% ZrO_2, 0 - 25 Mol-% CaO, 0 - 3 Mol-% As_2O_3 + Sb_2O_3 und 0 - 5 Mol-% ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5 enthält.

8. Glas gemäß Anspruch 1, welches eine Zusammensetzung aufweist, die als das Glas bildende Oxide von 25 - 50 Mol-% SiO_2, 20 - 40 Mol-% Al_2O_3, 8 - 30 Mol-% CaO, 2 - 15 Mol-% Y_2O_3 enthält.

9. Glas gemäß Anspruch 8, welches darüber hinaus 0 - 20 Mol-% MgO, 0 - 25 Mol-% TiO_2, 0 - 12 Mol-% Li_2O, 0 - Mol-% As_2O_3 + Sb_2O_3 und 0 - 5 Mol-% ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5 aufweist.

10. Glas gemäß einem der Ansprüche 1 - 9, wobei das Glas ein Young's Modul von 110 GPa oder mehr zeigt.

Revendications

1. Verre pour substrats ayant un module élastique spécifique G de 36×10^6 Nm/kg ou plus.

2. Verre selon la revendication 1 dont la rugosité de surface (Ra) peut être rendue égale à 0,9 nm (9Å) ou moins.

3. Verre selon la revendication 1 ayant une température de transition de 700°C ou plus.

4. Verre selon la revendication 1 ayant une composition, pour les oxydes constituant le verre, de 25-52 mole-% de SiO_2, 5-35 mole-% de Al_2O_3, 15-45 mole-% de MgO, 0-17 mole-% de Y_2O_3, 0-25 mole-% de TiO_2, 0-8 mole-% de ZrO_2, 1-30 mole-% de CaO, à condition que Y_2O_3 + TiO_2 + ZrO_2 + CaO représente 5-30 mole-% et que B_2O_3 + P_2O_5 représente 0-5 mole-%.

5. Verre selon la revendication 4 contenant 0-3 mole-% de As_2O_3 + Sb_2O_3 et 0-5 mole-% de ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5.

6. Verre selon la revendication 1 ayant une composition, pour les oxydes constituant le verre, de 25-50 mole-% de SiO_2, 10-37 mole-% de Al_2O_3, 5-40 mole-% de MgO, et 1-25 mole-% de TiO_2.

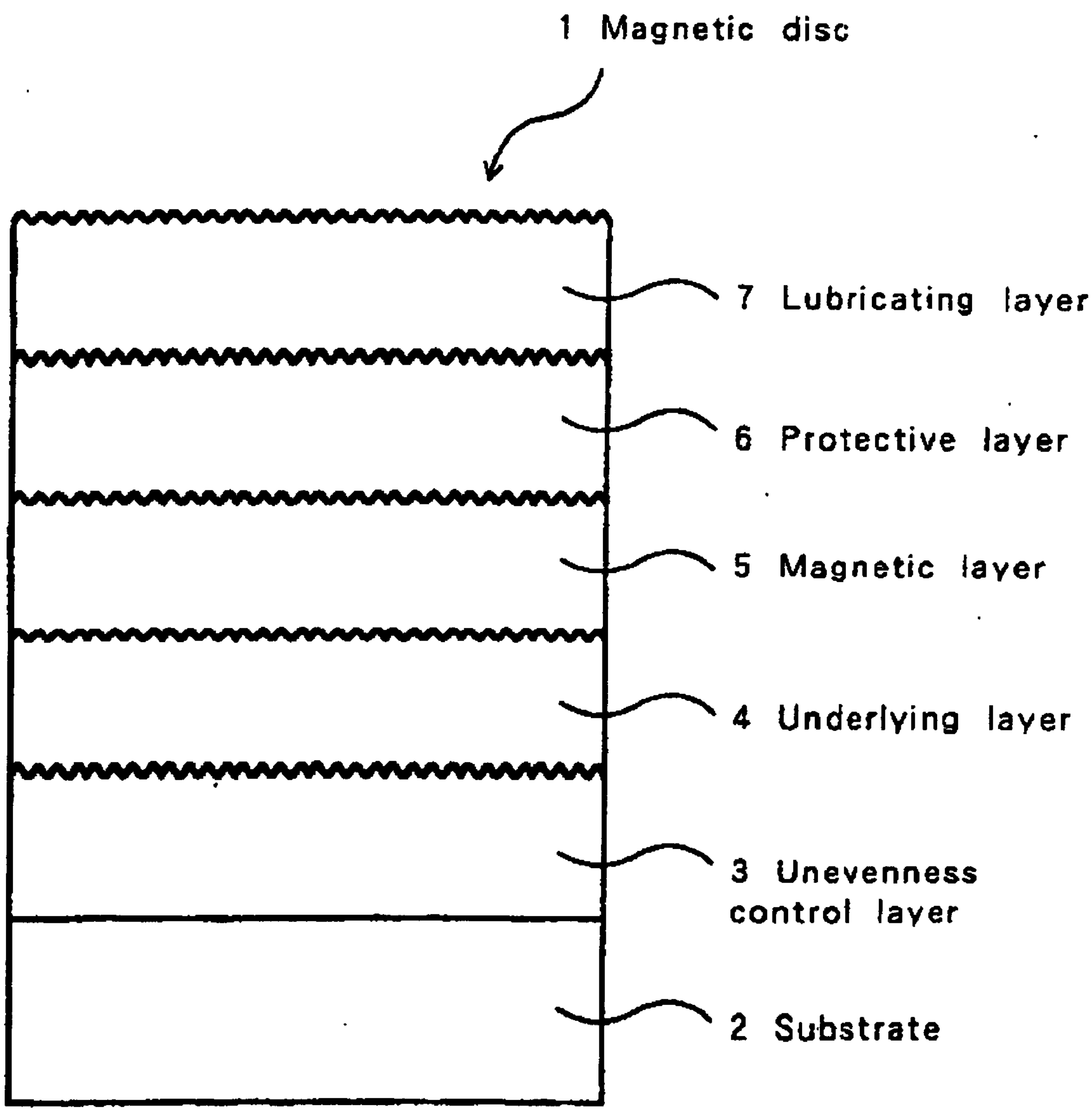
7. Verre selon la revendication 6 comprenant en outre 0-17 mole-% de Y_2O_3, 0-8 mole-% de ZrO_2, 0-25 mole-% de CaO, 0-3 mole-% de As_2O_3 + Sb_2O_3 et 0-5 mole-% de ZnO + SrO + NiO + CoO + FeO + CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5.

8. Verre selon la revendication 1 ayant une composition contenant, comme oxydes constituant le verre, 25-50 mole-% de SiO_2, 20-40 mole-% de Al_2O_3, 8-30 mole-% de CaO, 2-15 mole-% de Y_2O_3.

9. Verre selon la revendication 8 contenant en outre 0-20 mole-% de MgO, 0-25 mole-% de TiO_2, 0-12 mole-% de Li_2O, 0-3 mole-% de As_2O_3 + Sb_2O_3 et 0-5 mole-% de ZnO + SrO + NiO + CoO + FeO+ CuO + Fe_2O_3 + Cr_2O_3 + B_2O_3 + P_2O_5 + V_2O_5.

10. Verre selon l'une des revendications 1-9 dans lequel le verre présente un module d'Young de 110 GPa ou plus.

Fig. 1


1 Magnetic disc
7 Lubricating layer
6 Protective layer
5 Magnetic layer
4 Underlying layer
3 Unevenness control layer
2 Substrate